

THESIS FOR THE DEGREE OF LICENTIATE OF ENGINEERING

Digital model-driven retail supply chain management

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CHALMERS UNIVERSITY OF TECHNOLOGY

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Abstract

The purpose of this thesis is to increase the understanding of how matching of digital models of products and customers can be used to shift the performance frontier in retail supply chains. This thesis puts forward the matching of digital models as an operational practice used by retail supply chains. Digital product models are digital descriptions of available products on the market and they contain information about the products' characteristics. Digital customer models are digital descriptions of customers and contain customer characteristics and preferences. This thesis concerns product recommendations based on matching of digital product and customer models.

This thesis conceptualizes the operational practice of matching digital models of products and customers (Paper I), identifies potential supply chain outcomes by introducing the operational practice in retail supply chains (Paper II), and evaluates mechanisms driving the outcomes in two retail supply chains (Paper III). Exploratory design science research is used to conceptualize the operational practice, and case studies and a case survey are used to empirically evaluate supply chain outcomes and mechanisms that drive them.

Findings show how the operational practice moves the performance frontier by improving market mediation performance in retail supply chains, particularly through improved delivery performance and production cost performance. The findings imply that delivery performance and cost performance can be achieved without a trade-off between the two.

The practical contribution of this thesis is that the findings help companies understand how their profiles match the operational practice and gears them to achieve the outcomes. The thesis demonstrates how the operational practice would function in real-life and studies how existing similar practices produce the outcomes, which yields insight into hands-on knowledge that can be used by the companies. The thesis develops a maturity model, describing three maturity levels of the operational practice. Companies can map their current status and desirable to-be status in the model and advance in level.

The thesis contributes to theory by increasing the solution space for combining efficiency and responsiveness in retail supply chains by bypassing the trade-off between production efficiency and delivery performance through the use of new matching technology. Matching technology enables the operational practice to more fully utilize the existing product variety in already manufactured product supply to move the performance frontier in retail supply chains.

Keywords Digitalization, Digital product fitting, Digital product models, Digital customer models, 3D scanning, Product variety, Matching technology, Retail supply chains, Design science, Mass customization.

List of appended papers

This thesis is based on the work contained in the following papers:

Paper I

Gustafsson, E., Jonsson, P. and Holmström, J. (2018). "Digital Product Fitting: Design of a Novel Operational Practice for Efficient Response in Retail Supply Chains".

An earlier version of this paper was presented at the 29th Annual Nordic Logistics Research Network Conference (NOFOMA 2017), 8-9 June 2017, Lund, Sweden.

Paper II

Gustafsson, E., Jonsson, P. and Holmström, J. (2019). "Digital Product Fitting in Retail Supply Chains: Maturity Levels and Potential Outcomes".

An earlier version of this paper was presented at the 30th Annual Nordic Logistics Research Network Conference (NOFOMA 2018), 14-15 June 2018, Kolding, Denmark.

Paper III

Gustafsson, E., Jonsson, P. and Holmström, J. (2019). "Evaluating Mechanisms Driving Supply Chain Outcomes of Digital Product Fitting in the Efficient and the Responsive Retail Supply Chains".

The researcher's contribution to the papers

Paper	First author	Co-authors	Commitments
I	Emmelie Gustafsson	Patrik Jonsson and Jan Holmström	The first author gathered all data and wrote the larger part of all sections under supervision of co-authors. The paper took turns between authors and was improved jointly. Analysis and discussion were jointly written by all authors.
II	Emmelie Gustafsson	Patrik Jonsson and Jan Holmström	The first author gathered all data and wrote all sections of the paper under supervision of co-authors. The coding of cases was uniformly done by the first author and extensively discussed among all three authors.
III	Emmelie Gustafsson	Patrik Jonsson and Jan Holmström	The paper idea was proposed by co-authors and the paper structure was set up by the first author. The first author gathered all data and wrote all sections of the paper under supervision of co-authors.

Contents

1	Introduction	1
1.1	Problem discussion: matching supply and demand in retail supply chains	1
1.2	Opportunity to use matching of digital models	3
1.3	Purpose and research questions	5
1.4	Conceptual framework	5
1.5	Scope	7
1.6	Outline	7
2	Literature review: the main stream of research	9
2.1	Performance capabilities and manufacturing strategy	9
2.2	Supply chain design	10
2.3	Supply chain performance	12
2.4	Omnichannel	14
2.5	Synthesis of the research areas	15
3	Theoretical frame of references	17
3.1	Definition of digital models	17
3.1.1	Digital models as objects	18
3.1.2	Digital product models	18
3.1.3	Digital customer models	19
3.2	Definition of matching	19
3.3	Definition of retail supply chains	20
3.4	Digital model-driven retail supply chain management	21
3.5	Theory of performance frontiers	21
4	Methodology	25
4.1	Research process	25
4.2	Research phenomenon	26
4.3	Research design	27
4.4	Research approach	30
4.5	Case selection	32
4.5.1	Paper I	33
4.5.2	Paper II	34
4.5.3	Paper III	34
4.6	Data collection	35
4.6.1	Interviews	35
4.6.2	Direct observations	36
4.6.3	Secondary data	37
4.7	Data analysis	37
4.7.1	Paper I and III	37
4.7.2	Paper II	39
4.8	Research quality	40
4.8.1	Pragmatic validity	41

4.8.2	Practical relevance	43
4.8.3	Construct validity	43
4.8.4	External validity	43
4.8.5	Reliability	43
4.9	Research ethics and bias	44
5	Findings	45
5.1	RQ1 – Conceptualization	45
5.2	RQ2 – Potential supply chain outcomes and contextual fit . .	46
5.3	RQ3 – Mechanisms	48
6	Shifting the performance frontier	51
6.1	Key characteristics of the cases used for argumentation of a performance frontier shift	52
6.2	The theory of performance frontiers	53
6.2.1	Dress shoe customizer	54
6.2.2	Skates stocker	55
7	Discussion	59
7.1	Revisiting the CIMO framework	59
7.1.1	How the findings from RQ1 address the purpose . .	59
7.1.2	How the findings from RQ2 address the purpose . .	60
7.1.3	How the findings from RQ3 address the purpose . .	60
7.2	Contribution and significance: Shifting the performance frontier	61
7.3	Generalizability of results	62
8	Concluding remarks	65
8.1	Conclusions	65
8.2	Theoretical and managerial contribution	65
8.3	Limitations and further research	67
8.3.1	Actor perspective	67
8.3.2	Product and supply chain scope	68
8.3.3	Field-testing	69
	References	71
	Appended papers	81
	Paper I	81
	Paper II	111
	Paper III	141

List of Figures

1.1	How the research questions relate to one another	6
1.2	How the research questions relate to the purpose	7
2.1	Main takeaway from performance capabilities and manufacturing strategy	10
2.2	Main takeaway from supply chain design	12
2.3	Main takeaway from supply chain performance	14
2.4	Main takeaway from omnichannel retailing	15
2.5	Synthesis of the research areas	16
3.1	Concepts and theories used to address the purpose statement	17
3.2	The theory of performance frontiers, operating and asset frontiers	23
3.3	The theory of performance frontiers, the bettered frontier . .	24
4.1	Timeline of the research process	26
4.2	The research design of the thesis	29
4.3	A design science research framework	40
4.4	How the research in Paper I and II was performed	42
6.1	Shifting the performance frontier for Dress shoe customizer .	55
6.2	Shifting the performance frontier for Skates stocker	56

List of Tables

4.1	Case research applied in the appended papers.	33
6.1	Cross-case analysis of Dress shoe customizer and Skates stocker	52
6.2	Performance frontiers theory applied to the research context	54

1. Introduction

This thesis presents how matching of digital models of products and customers can be used to move the performance frontier in retail supply chains. An operational practice of matching digital product models with digital customer models is put forward, and from hereon, the term “operational practice” refers to the use of matching digital product and customer models. The operational practice is coined *digital product fitting*. This chapter takes a starting point in an anecdote highlighting the problem in context for this research.

Anecdote Sarah is searching for a new shirt, but her muscular arms makes it difficult to find a shirt that fits. To get a comfortable fit around the arms she needs to go up one or possibly two sizes. However, the larger shirt is far too wide for Sarah’s waist. Sarah is left with fitting issues since her body dimension differs from what is considered standard or normal. Sarah then looks up a store that sells customized clothes. Customization comes with greater production costs compared to ordinarily mass-produced off-the-shelf standard products. Sarah goes through the process of designing a fitting shirt, but unwillingly because all she desired was a smooth shopping experience, not being a designer or having to wait several weeks for delivery. At the same time, there is a local shop somewhere that possesses a fitting shirt for Sarah, a long-tail shirt in risk of becoming obsolete because its existence is unknown to external parties. Imagine then the vast amount of obsolescence and inventory holding costs that retail supply chains experience when mass-producing to stock.

1.1 Problem discussion: matching supply and demand in retail supply chains

In recent decades, the product variety supplied in retail supply chains has boomed. In retail, it is especially important to respond fast, yet cost-efficiently, to individual customer demand. However, increased product variety is closely associated with production efficiency challenges and results in higher inventory holding costs and obsolescence (Wan and Sanders, 2017). Increased product variety makes it challenging for manufacturing companies to foresee demand and maintain production efficiency. The result is a mismatch between supply and demand that either leads to a shortage of products indicated by local stock-outs at retailers’ shelves or a surplus of unsold outdated products that need price discounts for clearance (Holweg and Pil, 2001; Wan et al., 2012).

There is a delicate balance between the product variety offered and the costs associated with either lost sales due to a shortage of supply or inventory holding costs due to oversupply. The market mediation point is where supply matches demand. For retailers, the market mediation point is reached by adjusting the price of a product. For retail supply chains, the market mediation point is reached by adjusting the product supply either through production volume or product variants. Any deviation from the market mediation point results in either an oversupply or shortage of products on the market.

Fisher (1997) denotes the costs incurred by these balance point deviations as market mediation costs. The purpose of market mediation is to ensure that the product variety on the market matches customer demand. Market mediation costs are defined as costs that arise from a mismatch in supply and demand, such as obsolescence and lost sales (Fisher, 1997).

Market mediation is easy for functional products, i.e., products whose demand is easily predictable. Functional products typically have long life-cycles of two years or more. However, market mediation for innovative products is challenging. Innovative products typically have short life-cycles of less than a year and the demand is unpredictable (Fisher, 1997). The innovative products are prone to deviate from the point of balance due to the uncertain market reaction. When market mediating innovative products, it is important to sell the products early in the life-cycle for establishing market share, if the products fall short of supply, the costs related to lost sales increases the cost of shortages. Considering that innovative products typically have high profit margins, and that, in addition to lost sales, amplifies the cost of shortages. The short life-cycles of innovative products increase the market mediation costs related to an oversupply of products, especially obsolescence or by having to markdown products (Fisher, 1997). Market mediation is also challenging for long-tail products which are prone to becoming obsolete (Brynjolfsson et al., 2010).

Previous supply chain frameworks for achieving market mediation performance are, e.g., the product-process matrix (Hayes and Wheelwright, 1979), the supply chain-product matrix (Fisher, 1997), and the postponement/ speculation matrix (Pagh and Cooper, 1998). Notably, extant research has focused much on the fit between product characteristics and supply chain processes. Research has also been addressing lean production by reducing buffers, reducing lead times, and reducing demand volatility (Yin et al., 2017; De Treville et al., 2004; Hines et al., 2004). The counterpart to lean is agility, which addresses flexibility in production to better cope with volatile demand (Christopher and Towill, 2001).

These supply chain frameworks draw on manufacturing strategy literature. Manufacturing strategy literature focuses on factory-specific capabilities in matching the type of production type to the type of product (Hayes and Wheelwright, 1979; Skinner, 1974), whereas the supply chain frameworks by Fisher (1997) and Pagh and Cooper (1998) focus on matching product type with supply chain design. The manufacturing strategy literature is necessary for the

argumentation of the operational practice such that manufacturers produce products given their economic profit-maximization rationality (Ketokivi and Schroeder, 2004).

Solutions for providing customers with fitting products without neglecting production efficiency include integration of variety within a product (Gilmore and Pine II, 1997), postponement of the assembly point of a product until customer order comes in (Rudberg and Wikner, 2004), customization of an already mass-produced product (Lim and Istook, 2012), and direct manufacturing, such as 3D printing (Sodhi and Tang, 2017).

The difficulty with these mass customization solutions is their aim to produce affordable products with a sufficient degree of product variety and customization such that nearly all customers find what they want (Zipkin, 2001). Merle et al. (2010) argue that it is insufficient to provide efficient customization. “The perceived benefits that consumers derive from a specific mass customization offer are a key component of its success” (Merle et al., 2010, p. 503). Given that it is the perceived benefits that decide the success of a product, matching has great potential to inform the customer about products that match her desired benefits.

However, these solutions neglect the opportunities of more fully utilizing the product variety available in the already produced product supply.

1.2 Opportunity to use matching of digital models

Therefore, this thesis addresses the opportunity of fully utilizing available product supply and to match this to customer demand in order to mitigate the negatives of the market mediation costs (Fisher, 1997) arising from the mismatch in supply and demand. Matching supply and demand in operations management has thus far implied a strategic choice for companies to align their production with customer demand. The strategic choice implies a trade-off for producing companies between providing customized customer-specific products and producing the products as efficiently as possible. I.e., there is a trade-off between cost performance and delivery performance. This thesis takes a new approach to bypass this cost-delivery performance trade-off. What is put forward in this thesis is the use of matching technology.

Fisher and Vaidyanathan (2012) claim that customers do not simply buy products, but rather a bundle of attributes. For example, product selection in regard to TVs depends on the attributes of the TV, such as screen size, resolution, price, brand, etc. (Fisher and Vaidyanathan, 2012). Finding, or matching, the right product attributes is critical for a successful purchase for the customer. The notion of product attributes being an important aspect for providing customers with products that match their needs, carries opportunities in using technology that facilitates mapping of these attributes. Current applications

that map product attributes are, e.g., price comparison websites and product recommendation applications.

Matching is an established technology in information systems applications and is profoundly used for marketing purposes (Schrage, 2018). The matching technology typically goes under the notion of recommendation systems and its perhaps most relatable application area concerns online product recommendations (Schafer et al., 2001). Product recommendation systems use customer data, such as purchase history and online product browsing data. Recommender systems use such data to recommend products that match the gathered customer data. Some product recommendation systems are very complex using neural network logic to predict customer preferences, such as Spotify for music and Netflix for movies (Schrage, 2018).

Product recommendation systems can, therefore, be said to match digital product models with digital customer models. In this thesis, a digital product model is defined as a digital product description which contains characteristics pertained to the product, and such characteristics could be any parameter necessary to describe the product. A digital customer model is defined as a digital customer description which contains characteristics pertaining to the customer. In the case of Netflix, the digital customer models could contain previous watch history, age, completion rate (if the customer stopped watching before the end of the movie), etc. The digital product model could contain genre, which type of customers that typically watch the movie, age restriction, etc. The product recommender in Netflix then matches movies to the customer based on the customer characteristics in the digital customer model.

This thesis draws on four main research areas, namely; manufacturing strategy (Skinner, 1974; Ketokivi and Salvador, 2007; Swink et al., 2005), supply chain design (Fisher, 1997; Pagh and Cooper, 1998), supply chain performance (Um et al., 2017; Gunasekaran et al., 2001; Wan et al., 2012; Sandberg and Jafari, 2018; Schmenner and Swink, 1998), and omnichannel retailing (Chopra, 2018; Brynjolfsson et al., 2013). The thesis studies and proposes how the use of digital models of customers and products can be matched to bypass the cost-delivery performance trade-off in retail supply chains, i.e., to move the performance frontier (Schmenner and Swink, 1998).

Delivery performance is considered as the retail supply chain's ability to provide customer-specific products with no, or very short lead time, often directly off-the-shelf. Given that the operational practice uses the already available product supply on the market, maximum delivery performance is achieved. Cost performance is considered as the retail supply chain's ability to produce products cost-efficiently. Given the companies' economic profit-maximization rationality (Ketokivi and Schroeder, 2004), the available products on the market are produced using high productivity which enables cost-efficiency. By matching available product supply to customers in need or want of it, cost performance and delivery performance are achieved without a trade-off between the two.

Next, the purpose and research questions follow.

1.3 Purpose and research questions

The purpose of this thesis is to increase the understanding of how matching of digital models of products and customers can be used to shift the performance frontier in retail supply chains. By introducing a new technology in the form of an operational practice, it is possible to shift the performance frontier such that higher levels of performances can be achieved simultaneously, which previously was unachievable. To do so, an operational practice (i.e., digital product fitting) needs to be designed and defined. The operational practice needs further evaluation in terms of potential outcomes by introducing it in retail supply chains, for which contexts it is relevant, and what mechanisms that drive the outcomes.

This thesis comprises three research questions. The first research question leads the research for exploring how matching of digital product and customer models can be operationally used in retail supply chains.

RQ1 How can matching of digital product and customer models be operationally used in retail supply chains?

The operational practice intends to match supply and demand in retail supply chains in both a cost-efficient and responsive manner in order to move the performance frontier. To understand how retail supply chains can deliver both cost performance and delivery performance, it is important to research what potential outcomes the operational practice may result in. It is further important to explore the contextual fit of the operational practice. RQ2 leads the research for proposing potential outcomes by introducing the operational practice in retail supply chains, and for investigating the contextual fit.

RQ2 What are potential supply chain outcomes by introducing the operational practice in a retail supply chain?

The third research question leads the research for empirically evaluating how mechanisms contingently drive supply chain outcomes induced by the operational practice in two particular retail supply chains. Understanding the mechanisms is of utter importance for understanding *why* outcomes occur and *how* to control the outcomes.

RQ3 How do mechanisms contingently drive supply chain outcomes induced by the operational practice?

Next follows how the research questions relate to one another in the conceptual framework of the thesis.

1.4 Conceptual framework

Figure 1.1 shows how the research questions relate to one another within the CIMO-logic framework. The research is positioned within the CIMO-logic framework, which reads: “[...] in this class of problematic **C**ontexts, use this **I**ntervention type to invoke these generative **M**echanism(s), to deliver these **O**utcome(s)” (Denyer et al., 2008, p. 395).

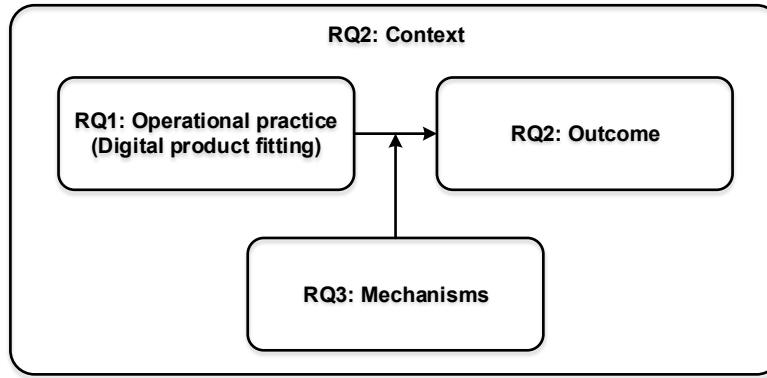


Figure 1.1: How the research questions relate to one another.

The four constituents of the CIMO framework form, what [Denyer et al. \(2008\)](#) term, a *design proposition*. Design propositions constructed using the CIMO framework detail what to do, in which context, to produce what outcomes, and offer an understanding of why this occurs. A design proposition is, therefore, descriptive and details what to do, in which context, to produce what outcomes, and offer an understanding of why this occurs as the intervention is operationalized.

However, this thesis does not develop much of a descriptive design proposition based on field observations. Instead, it explores current practices and frames a *prescriptive* design proposition. Here, prescriptive implies that the design proposition details how the operationalization of the intervention *should* or *ought* to be. This thesis conforms to the practice-based view, which suggests that studies focusing on company performance should develop specific and actual techniques that can be used and implemented by the companies ([Bromiley and Rau, 2016](#)). Often, approaches to company performance regard macro-level company characteristics and the influence of such characteristics on company performance (such as Fisher's (1997) strategic supply chain design framework), but seldom result in hands-on operational knowledge ([Bromiley and Rau, 2014](#)). This thesis adopts the practice-based view and puts forward an operational practice attempting to improve retail supply chain performance.

The research involves studying and conceptualizing an operational practice as a foundation for developing a more case-based, descriptive design proposition, in a later stage beyond this thesis. In the CIMO framework, the operational practice is the intervention but it refers to a *proposed* intervention since the operational practice has not been field-tested. An intervention details what to do and requires field-testing. The operational practice could have been referred to as a concept, but since the practice has not yet been established as a theoretical concept in operations and supply chain literature, it was decided to refer to an operational practice.

The set of research questions, hence, contributes to an understanding of the operational practice that aims to combine responsiveness and efficiency in

retail supply chains in order to shift the performance frontier. Figure 1.2 shows how the research questions relate to the thesis purpose.

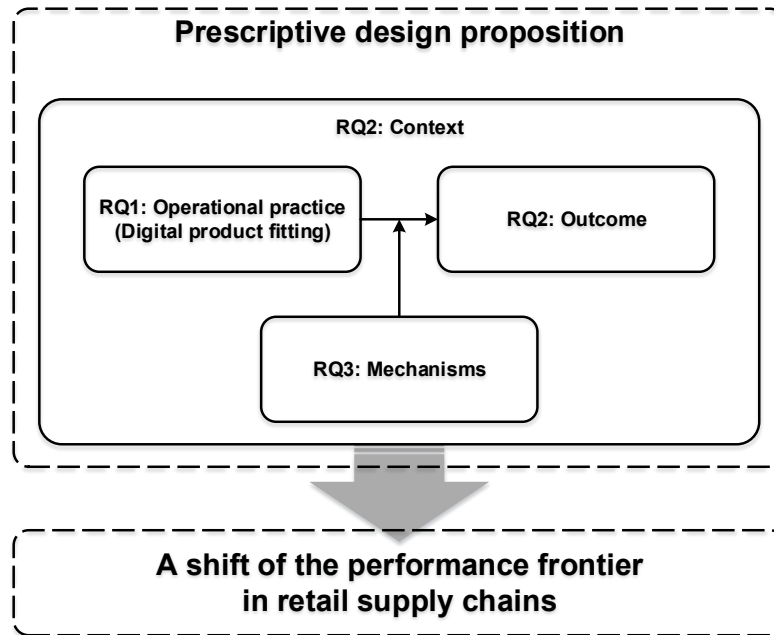


Figure 1.2: How the research questions relate to the purpose.

1.5 Scope

This thesis addresses retail supply chain performance through the use of matching technology. Retail supply chains are different from supply chains of other industries. A differentiation factor is that retail supply chains involve large volumes of fast-moving products. Fast-moving implies that products need to be supplied responsively through physical flows to keep up with the fast-moving market life cycle and customer demand. Another differentiation factor is that retail supply chains are end-to-end, meaning that they stretch to include the end-user. It naturally follows that end-users are subject for analysis in retail supply chains, however, this thesis does not address the end-user, but regards matching of digital models as an interface between the retailer and the end-user. The interface, hence, enables upstream supply chain actors to access end-user data pertained in the digital customer models. Thus, the scope of this thesis concerns the actors upstream from the end-user, and the focus is on the supply of products.

Next, follows brief content descriptions of the chapters in this thesis.

1.6 Outline

This thesis consists of eight chapters with contents as follows.

Chapter 1: Introduction begins by presenting an anecdote illustrating the problem in context in this research, i.e., the problem of ill-fitting products from both the end-user perspective as well as from the operations

and supply chain management perspective. The latter perspective is the focus of the thesis and is further elaborated upon in the problem discussion section. Next, the purpose and the three research questions are presented. The research questions are put into a conceptual framework which relates the research questions to one another. The last section is the scope of the thesis.

Chapter 2: Literature review: the main stream of research reviews previous literature relevant for matching supply and demand in retail supply chains. The literature review enables positioning of the research within established research streams and provides an insight into what has been researched in regard to the cost-delivery performance trade-off.

Chapter 3: Theoretical frame of references describes the operational practice by giving definitions of digital models and matching, and what is meant by a digital model-driven retail supply chain. It further presents the theory of performance frontiers to lay the foundation for analyzing how the research findings move the performance frontier.

Chapter 4: Methodology begins by describing the research process and summarizes it as a timeline. Then, the research phenomenon in the research is presented as the interface between digital product models and digital customer models, how these can be matched and located in existing product variety already available in the vast product supply. The research design is design science research combined with case research. Then, case selection, data collection, data analysis, and research quality are described. The chapter ends with a reflection on research ethics and bias.

Chapter 5: Findings summarizes the findings from the three appended papers.

Chapter 6: Shifting the performance frontier synthesizes the research findings and analyzes how these shift the performance frontier in retail supply chains to address the purpose statement of this thesis.

Chapter 7: Discussion revisits the CIMO framework and discusses how the research question findings address the purpose of the thesis. The contribution and significance of the research findings in terms of the research purpose are highlighted. The chapter ends with a discussion on the generalizability of the research findings.

Chapter 8: Concluding remarks concludes the research and addresses the significance of the research in terms of its theoretical and managerial contribution. The chapter ends by setting new directions for further research.

2. Literature review: the main stream of research

This chapter reviews previous literature relevant for matching supply and demand in retail supply chains. The literature review enables positioning of the research within established streams of research and provides an insight into what has been researched in regard to the cost-delivery performance trade-off. This chapter lays the foundation for the operational practice.

An early stream of research has been manufacturing strategy with seminal work by Skinner (1974; 1996). Main streams of research include designing the supply chain to be either efficient or responsive (Fisher, 1997). Pagh and Cooper (1998) draw on the same logic proposed by Fisher (1997), but suggest four different designs depending on the desired level of efficiency and responsiveness. Mass customization has also been a popular research area with seminal studies such as Van Hoek (2001) and Salvador et al. (2002). Another stream of supply chain design research has been lean and agile (Christopher and Towill, 2001). Information technology has a significant impact on supply chain performance in promoting information sharing between supply chain actors (Gunasekaran and Ngai, 2004). More recently, information technology has enabled omnichannel retailing which has achieved much attention (Brynjolfsson et al., 2013; Chopra, 2018).

This chapter presents the research areas one by one, and after each research area follows a main takeaway from the research area. The takeaways form a synthesis of previous research and the concluding Figure 2.5 shows how the operational practice draws on the four research areas.

2.1 Performance capabilities and manufacturing strategy

Early research in performance capabilities and manufacturing strategy is Skinner's (1974) article about the focused factory. The term *capabilities* is loosely defined in literature but can be said to involve resources that enable specific performances. Skinner (1974) introduced factory focus, which implies that factories should focus on their core competencies and competitiveness to stop compromising trade-offs within the factories. Skinner's (1974) factory focus has later been expanded by, e.g., Ketokivi and Jokinen (2006) and Ketokivi and Salvador (2007).

Manufacturing strategy literature has to a large extent dealt with competitive priorities in manufacturing, and inter-relationships of competitive objectives such as cumulative capabilities (Boyer and Lewis, 2002; De Meyer et al., 1989; Ward et al., 1998; Swink et al., 2005). These streams suggest that

strategic use of resources leads to market competitiveness and factory performance.

Early manufacturing strategy literature is focused on factory performance. In later times, the supply chain became the focus of performance. As per early year 2000, [Brown and Bessant \(2003\)](#) state that little attention has been devoted to investigating the manufacturing strategy applied to other paradigms, such as agility and mass customization. [Brown and Bessant \(2003\)](#) imply that if companies attempt to become agile and adopt a mass customization approach to manufacturing, there is a risk that the contribution of factory-specific manufacturing strategies is lost. The theory of performance frontiers builds on manufacturing strategy research, and is a central theory for the operational practice studied in this thesis. The theory of performance frontiers is presented in Chapter 3.

Figure 2.1 shows the main takeaway from the production capabilities and manufacturing strategy research area. The main takeaway is that factory focus lets manufacturers take advantage of their factory-specific capabilities to produce products using high productivity.

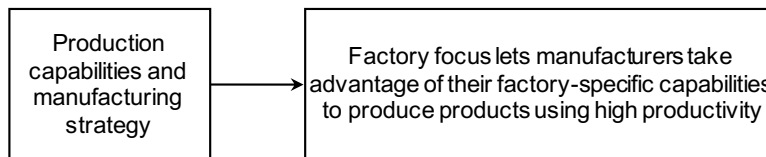


Figure 2.1: The main takeaway from the research area of performance capabilities and manufacturing strategy.

2.2 Supply chain design

Designing for the right type of supply chain for the product supplied is essential in achieving supply chain performance and has been a major stream of research during the last decades. Notably, such seminal literature consists of the product-process matrix ([Hayes and Wheelwright, 1979](#); [Flynn et al., 1999](#)), the supply chain-product matrix ([Fisher, 1997](#)), and the postponement-speculation matrix ([Pagh and Cooper, 1998](#)).

[Fisher \(1997\)](#) proposed that if the product supplied is of functional character with predictable demand, then the efficient supply chain is the best choice. Innovative products require a responsive supply chain to respond quickly to demand and to minimize stockouts, price reductions, and obsolescence that unsuccessful innovative products otherwise involve ([Fisher, 1997](#)). Unsuccessful products (i.e., products which have not been sold, nor will be sold) in retail supply chains require multiple price discounts to clear inventory from obsolescence. Strategies for retailers to battle demand uncertainties and to mitigate obsolescence include frequently changing collections, using quick response sourcing, and data-driven channel switching ([Zhang et al., 2017](#)). Strategies for manufacturers include modularization ([Salvador et al., 2002](#)),

postponement of the assembly point (Van Hoek, 1998), and build-to-order (Gunasekaran and Ngai, 2005).

Increasing the need for build-to-order production reduces the opportunity to take advantage of economies of scale. Research shows that customization is associated with low productivity, low efficiency, and high costs in relation to its counterpart, standardization (Fogliatto et al., 2012; Holweg and Pil, 2001). Considering costs from four perspectives: distribution costs, production costs, inventory costs, and obsolescence costs (Elrod et al., 2013), build-to-order increases production and distribution costs due to one-piece flow through production and customized distribution and handling. Consolidation and batching reduce these costs for make-to-stock while increasing inventory and obsolescence costs (Fisher, 1997; Hayes and Wheelwright, 1979). Obsolescence costs are related to outdated inventory and often cannot be completely eliminated, but can be managed and mitigated (Elrod et al., 2013). Build-to-order entails lower inventory levels (if any) than make-to-stock, therefore, it follows that build-to-order is associated with less risk of obsolescence than that of make-to-stock production.

Companies often make a choice either to have an efficient supply chain or a responsive supply chain (Pagh and Cooper, 1998), but it is also possible to have two differentiated supply chains for either purpose or to combine them through adopting a mass customization approach (Van Hoek, 2001).

Mass customization has been a widely known and accepted concept in the manufacturing market since it once arose in 1987 (Davis, 1987). It promised advantages in an attempt of combining economic efficiency with a sufficient degree of customization to satisfy customer demand. However, mass customization has failed to ultimately deliver what it once was thought to deliver (Zipkin, 2001; Gilmore and Pine II, 1997). The flaw lies in *sufficient* degree of customization.

Sufficient, as in good enough, is not always good enough in regard to customer value. Managers discovered that customer value was not examined thoroughly enough before mass customization was employed as a production strategy (Gilmore and Pine II, 1997). The result is a trade-off between sufficient customer value and sufficient production economies, yet the trade-off is not ideal for either of the two aspects (Heikkilä, 2002).

Lean and agile are concepts that followed mass customization. Whereas lean manufacturing focuses on continuous material flows, reduction of lead times, and cost reduction (Hines et al., 2004; De Treville et al., 2004; Christopher and Towill, 2001), agility promotes flexibility to be able to switch between production processes quickly, i.e., to be able to cope with volatility in demand (Christopher and Towill, 2001). Lean and agile supply chain designs are alternative notions of responsive and efficient supply chains as proposed by Fisher (1997). The market winner for lean supply chains is cost, whereas the market winner for agile supply chains is service level, or availability (Mason-Jones et al., 2000). The leagile supply chain is a combination of lean and agile and

arose as an attempt of combining the two to achieve a cost-efficient supply chain with the ability to adopt to volatility in demand.

Figure 2.2 shows the main takeaway from the supply chain design research area. The main takeaway is that an efficient make-to-stock supply chain should be used for supplying functional products with predictable demand and it favors economies of scale.

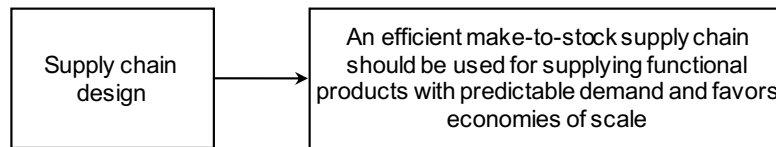


Figure 2.2: The main takeaway from the research area of supply chain design.

2.3 Supply chain performance

Vast product variety influences supply chain performance negatively (Um et al., 2017). Supply chain performance is a topic in operations management that has received much attention. Gunasekaran et al. (2001) provides an extensive performance measures review and found 41 supply chain performance metrics. For the purpose of this thesis, I settle with Boyer and McDermott (1999) and Schmenner and Swink (1998) articulated performance measures of quality, cost, delivery, and flexibility, which group many of the performance measures by Gunasekaran et al. (2001). Here, the performance measure of costs is of most interest. Elrod et al. (2013) consider costs from four perspectives: distribution costs, production costs, inventory costs, and obsolescence costs, all belonging to the operational level of supply chain management and thus suitable for the cost-delivery performance trade-off.

Squire et al. (2009) empirically study quality, cost, delivery, and flexibility and if the degree of product customization affects the four. The findings show that the trade-off persists between customization and manufacturing costs and delivery lead times. Which performance measures that matter the most can be linked to the supply chain configuration. Qi et al. (2017) performed a study on understanding operations strategies in supply chain configurations and arrived at the conclusion that lean supply chains prioritize the measures of cost, quality, and delivery, whereas agile supply chains prioritize flexibility. Qi et al. (2017) further stress that lean supply chains are more dependent on external supply chain integration compared to agile supply chains, although both supply chain types require high levels of integration. Um et al. (2017) investigate how variety management, supplier partnerships, and close customer relationships influence supply chain flexibility (reaction capability) and agility (reaction time). They found that, for external integration, customer relationships influenced flexibility, and partnerships influenced agility. It can be concluded that the appropriate supply chain configuration is of great importance for companies to meet their operations goals (Qi et al., 2017). The operational practice enables companies to pursue their operations goals by letting them focus

on economies of scale, whereas mass customization enables a sufficient degree of economies of scale (Piller and Kumar, 2006). Ye et al. (2018) studied the impacts of product modularity on new product development outcomes. The findings revealed that modularity does, in fact, have a positive impact on new product development outcomes. Some of the outcomes accounted for are, e.g., vaster product variety, improved product quality, shorter lead times, economies of scale, shorter time-to-market, and cost reduction regarding product design efforts and inventory holding.

There are also the financial performance measures, which both Wagner et al. (2012) and Hallavo (2015) use in their studies. Wagner et al. (2012) studied the link between supply chain fit (i.e., how well products' supply and demand uncertainty matched the supply chain configuration) and the financial performance of the company. The findings indicate that there is a correlation between supply chain fit and the return on assets. Both studies conclude that the larger the misfit, the lower the performance.

Customers are in the center for financial performance of a company. Rexhausen et al. (2012) study the impact of customer-facing supply chain practices on supply chain performance in relation to demand and distribution management. They conclude that high demand management performance has a positive impact on overall supply chain performance, and "this effect is stronger than that of distribution management" (Rexhausen et al., 2012, p. 269). The operational practice relates to this research by being an innovative customer-facing supply chain practice, and these practices have a large impact on supply chain performance, nonetheless in the retail setting. Seo et al. (2014) claim that supply chains should endeavor a high level of supply chain integration to effectively transform innovativeness into performance. "Innovativeness is seen as a complex process that handles environmental and technological uncertainty to seek and adopt new processes, ideas, products, and technologies for satisfying customers" (Seo et al., 2014, p. 733). Retail supply chains are keen on satisfying end-customers.

Providing vast product variety, or a broad product range/assortment, is an enabler for satisfying customer demand, and such research findings dominate, see e.g., Boyd and Bahn (2009); Brynjolfsson et al. (2003); Kekre and Srinivasan (1990). Vast product variety poses careful attention to inventory levels in retail stores. Ton and Raman (2010) conducted a longitudinal study investigating the effect of product variety and inventory levels in retail stores. Their findings show that both increased product variety and inventory levels in retail stores lead to higher sales, but it also has a negative sales impact through phantom products (available inventory in the storage area of a store, but unavailable to the customers). That products are available in the store, but not available to the customer is a much common problem for empty shelves in retailing.

Figure 2.3 shows the main takeaway from the supply chain design research area. The main takeaway is that efficient supply chains are cost-focused,

whereas responsive designs are delivery-focused. Availability is the most crucial performance measure in retailing.

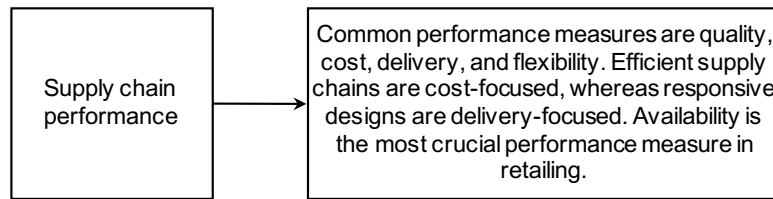


Figure 2.3: The main takeaway from the research area of supply chain performance.

2.4 Omnichannel

The emergence and application of new technology facilitate new ways of operating in the retail supply chain (Brynjolfsson et al., 2013). Retailers can now interact with end-users through multiple touch points and gather data about them but also expose them to online content. Omnichannel retailing is sometimes denoted as a “seamless retailing experience”, where all touch points are integrated, and the distinction between physical and web channels will vanish.

Nevertheless, physical retailing has inherent advantages in interacting with customers and acting as showrooms where customers can test, feel, and examine products (Chopra, 2018). Companies see advantages in establishing physical stores as the online retail market is becoming more competitive. Big online retailers, such as Amazon, have gone from only offering online shopping to launching physical stores as well (Bensinger and Stevens, 2016; Walsh, 2016).

Both physical retailers and online retailers face operations and supply chain management challenges. For example, physical stores find it difficult to transform potential customers that browse merchandise to paying customers. Once a customer finds an appealing product, the customer completes purchase online to attain a lower price or get a variant missing in the physical store. This is a growing problem for physical stores because physical retail chains receive no value for showrooming merchandise when customers turn to other channels to close the deal. On the other hand, online retailers suffer from massive return logistics due to products returned due to poor fit or wrong feel and texture of the ordered product (Degeratu et al., 2000; Lee and Bell, 2013). Thus, product fitting by the customer, i.e., the customer activity of selecting mass-produced products, has emerged as an important operational step in the retail sales process for both physical and online retailers.

The retail sector is introducing digital and Internet-connected services in physical retail (Hagberg et al., 2016). Emerging technologies also make it easier for physical retailers to develop new and more efficient solutions for product fitting that leverages their operational advantage in being in direct physical

contact with the customer. Specifically, such technology is 3D modeling and scanning (Cho et al., 2010). 3D modeling also carries advantages for upstream actors to endeavor product development excellency (Tan and Vonderembse, 2006).

The general trend in retailing is that the retail sector is going from being transaction and delivery-driven to helping end-users with their shopping (Brynjolfsson et al., 2013). Technology such as location-based applications on mobile devices enables such transformation. Omnichannel retailing is a new stream of research and also an attempt for solving the cost-delivery trade-off. Omnichannel implies that the best of physical retailing is combined with the best of web retailing such that omnichannel retail supply chains can be both cost-efficient and responsive to customer needs (Chopra, 2018). The key to successful omnichannel retailing is to use the different channels based on demand uncertainty, information complexity, and value of the products supplied. The physical channel should, hence, be used to cost-efficiently supply products whose demand is frequent and predictable. The web channel should be used to provide variety to the end-users and serve sporadic needs (Chopra, 2018; Brynjolfsson et al., 2010). The omnichannel framework is similar to the framework proposed by Fisher (1997), but new technology and delivery options take the framework to new levels and allow for a more contemporary efficiency/ responsiveness approach.

Figure 2.4 shows the main takeaway from the supply chain design research area. The main takeaway is that different marketing channels are preferred based on demand uncertainty, information complexity, and value of the products supplied. The physical channel promotes the cost-efficient supply of products whose demand is frequent and stable. The web channel promotes the provision of variety and serving sporadic needs.

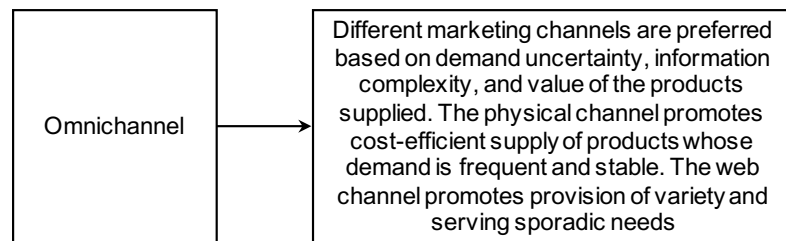


Figure 2.4: The main takeaway from the research area of omnichannel.

2.5 Synthesis of the research areas

The purpose of this thesis is to increase the understanding of how matching of digital models of products and customers can be used to shift the performance frontier in retail supply chains. Shifting the performance frontier implies that the cost-delivery performance trade-off can be bypassed, i.e., both production cost performance and delivery performance can be reached simultaneously. Previous research has extensively researched how production can be performed as efficiently as possible using factory focus (Skinner, 1974;

Ketokivi and Salvador, 2007), but also how delivery of products can be performed as responsively or efficiently as possible depending on how the supply chain is designed (Fisher, 1997; Christopher and Towill, 2001; Gunasekaran et al., 2001). Resource utilization, which is central in manufacturing strategies, is also important for supply chain design, especially in terms of lean/agile or efficient/responsive. Information technologies have facilitated information sharing between supply chain actors for better being able to streamline downstream demand upstream in the supply chain (Tan and Vonderembse, 2006; Gunasekaran and Ngai, 2004). The prevalence of information technology has facilitated integration of marketing channels and given rise to omnichannels. Figure 2.5 shows the synthesis of the research areas and how the operational practice draws on them.

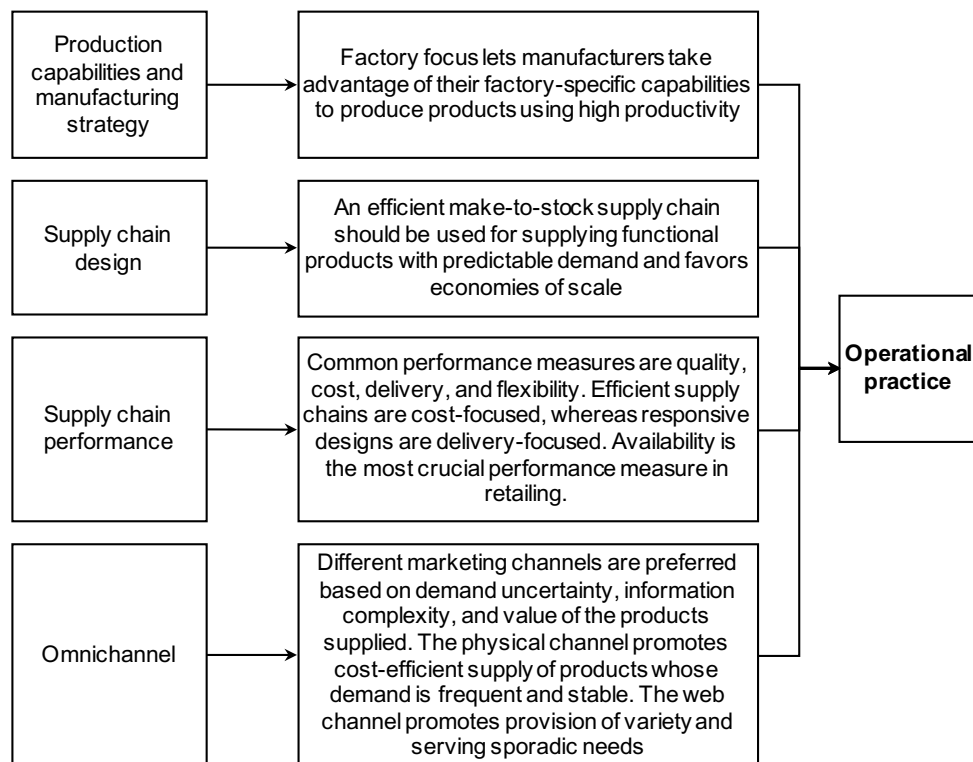


Figure 2.5: Synthesis of the research areas and how the operational practice draws on them.

3. Theoretical frame of references

This chapter presents necessary explanations to concepts and theories used to address the purpose statement of this thesis, i.e., to increase the understanding of how matching of digital models of products and customers can be used to shift the performance frontier in retail supply chains. In contrast to the literature review, this chapter describes the operational practice by giving definitions of digital models, matching, and retail supply chains and provides the reader with an understanding of what is meant by “digital model-driven retail supply chain management”.

Necessary explanations include definitions of digital models, matching, and retail supply chains. These concepts are combined and together they form what is termed digital model-driven retail supply chain management. The theory of performance frontiers is applied, and, in Chapter 6: Shifting the performance frontier, it is elaborated how matching of digital models in two retail supply chains enables a shift of the performance frontier. This chapter elaborates on the first five boxes (counted from the left) in Figure 3.1.

After having read this chapter, the reader understands the underlying premises that this research is based on.

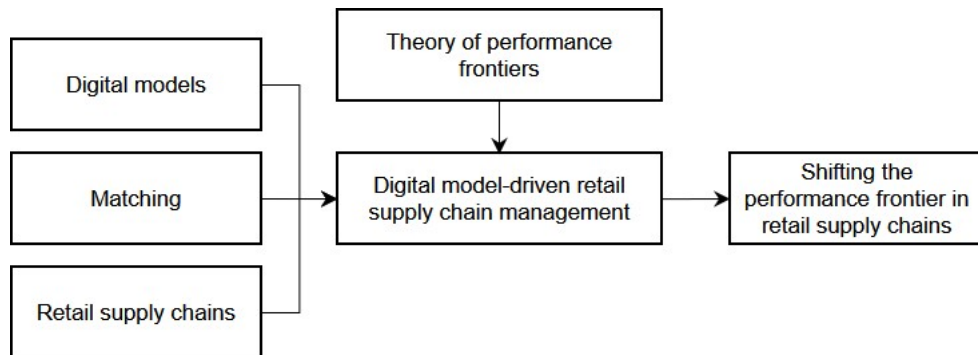


Figure 3.1: Concepts and theories used to address the purpose statement.

3.1 Definition of digital models

In this thesis, digital models are meant by digital descriptions of 1) actual products in the product supply, and 2) actual customers. The first is denoted as digital product models and the latter is denoted as digital customer models.

3.1.1 Digital models as objects

A digital model can be described with object-oriented programming terminology. Class-based object-oriented programming is based on objects, these objects contain data often referred to as attributes (Deitel and Deitel, 2012). Almost any noun can be represented as an object, e.g., there are time objects, date objects, audio objects, video objects, car objects, and people objects, etc. Objects are instances of classes, and the objects' attributes are defined by their class (Deitel and Deitel, 2012).

Classes provide standardization in what is contained in the objects of the classes. Attributes are object-specific and describe the object and are specified as part of the object's class. Examples of attributes are size, color, and shape. An object can contain as many attributes as is specified by its class (Deitel and Deitel, 2012). For example, a bank account object pertains to the class *bank account*. Each bank account object has the attribute *bank account balance*, which specifies the amount of money on the account. All bank account objects have the bank account balance attribute, but the actual attribute values are unknown to the other objects.

Classes can inherit the attributes specified by other classes. The new class contains the attributes of the class which it inherited, but it is also possible to customize the attributes and add new ones. For example, in a car analogy, the class *convertible* can inherit the more general class *car*, but in addition to the car class attributes, the convertible class also contains an attribute describing that the roof can be raised or lowered.

Despite my previous experience and fondness of programming, this thesis is not subject to it. Nevertheless, explaining the digital models as objects is an effective way of communicating what a digital model is. Up next follows what is meant by digital product models and digital customer models in this thesis.

3.1.2 Digital product models

A digital product model is defined as a digital product description (cf., object) which contains characteristics (cf., attributes) pertained to the product. Such characteristics could be any attribute necessary to describe the product. In the programming terminology, a digital product model is an instantiated object of the class *product*. For example, there could be a shirt object (digital product model) pertaining to the product class *apparel* which has the attribute values:

```
size = medium,  
color = navy blue,  
material = stretch, and  
type = long-sleeved.
```

In this thesis, digital product models represent actual product supply, i.e., each and every product and product variant in the product supply has a digital model equivalent.

3.1.3 Digital customer models

A digital customer model is defined as a digital customer description (cf., object) which contains characteristics (cf., attributes) pertaining to the customer. Such characteristics could be any attribute necessary to describe the customer, either through describing the customer in terms of, e.g., height, weight, age, or through desired preferences that the customer inputs to the digital model herself. In the programming terminology, a digital customer model is an instantiated object of the class *customer*. For example, there could be an Emmelie object (digital customer model) pertaining to the customer class which has the attribute values

```
height = 165 cm,  
weight = 62 kg,  
age = 28 years old, and with preference attributes,  
looks for = 'long-sleeved shirt',  
desired color = 'navy blue'.
```

In this thesis, digital customer models represent actual customer demand, i.e., each and every customer has a digital model equivalent.

Up next follows a definition of matching technology, where it is explained how digital product and customer models can be matched.

3.2 Definition of matching

Matching is, here, defined as the process of finding a corresponding equivalent to a digital model, either representing a customer or a product. Matching is an established technology in information systems applications and is profoundly used in marketing (Schrage, 2018). Matching can be used as a B2C interface that facilitates product selection by the end-customer.

The matching technology typically goes under the notion of product recommendation systems and its perhaps most relatable application area concerns online product recommendations (Schafer et al., 2001). Product recommendation systems use customer data, such as purchase history and online product browsing data. Recommender systems use such data to recommend products that match the gathered customer data. Some product recommendation systems are very complex using neural network logic to predict customer preferences, such as Spotify for music and Netflix for movies (Schrage, 2018).

Product recommendation systems can, therefore, be said to match digital product models with digital customer models. In the case of Netflix, the digital customer models could contain previous watch history, age, completion rate

(if the customer stopped watching before the end of the movie), etc. The digital product model could contain genre, which type of customers that typically watch the movie, age restriction, etc. The product recommendation algorithm in Netflix then matches movies to customer based on the customer attributes in the digital customer model.

3.3 Definition of retail supply chains

Conducting research in the field of retail supply chain management has increased in popularity during the last decades ([Sandberg and Jafari, 2018](#)). Nevertheless, few articles define a retail supply chain, but rather elaborate on some characteristics of a retail supply chain ([Sandberg and Jafari, 2018](#); [Barratt and Oke, 2007](#); [Randall et al., 2011](#)).

In common for retail supply chains is that they typically consist of four actors: manufacturers, distributors or wholesalers, retailers, and end-customers who are the final users of the retailed products. The manufacturers produce the products and sell them to wholesalers in large quantities. The wholesalers sell the products to retailers in small quantities. The retailers then sell the products to the end-users who use the products for their own personal use. Any business which sells products to the end-user is engaged in retailing. Retail supply chains are, therefore, considered as business-to-consumer and are limited from business-to-business sales, although exceptions exist ([Farfan, 2018](#)).

A retail supply chain includes the retailers and is hence retailer and end user-centric ([Randall et al., 2011](#)). Another differentiation factor is that retail supply chains involve large volumes of fast-moving products. Fast-moving implies that products need to be supplied fast through physical flows to anticipate the fast-moving market life cycle and customer demand ([HCL Technologies, 2018](#); [Hufford, 2017](#)).

Retail supply chain manufacturers typically run large batches for manufacturing efficiency purposes, resulting in high inventory levels throughout the supply chain. For counteracting the bullwhip-effect ([Lee et al., 1997](#)) and keeping inventories low, retailers usually place orders frequently and in small quantities. The frequent ordering combined with the small order quantity result in replenishment of mixed pallets, i.e., pallets packed with more than one SKU number. The retailers receive the goods on pallets or rolling cages, which have been manually packed at a distribution center or wholesaler, and which is manually replenished at the retailers' shelves ([Van der Vlist, 2007](#)).

Typical products retailed in retail supply chains are, e.g., clothing, footwear, sports equipment, groceries, and cars. The products are retailed using various channels, e.g., physical channels, web channels, or an integration of the two (multichannel). More recently, omnichannels have appeared.

In this thesis, the retail supply chain does not include the end-user per se. In lieu, the retailer's importance in being in direct contact with the end-customers

is regarded as a powerful benefit of the retail supply chain. Hence, this research regards the interface between the retailer and the end-customer, and more so through matching digital product and customer models to achieve positive supply chain outcomes by using these models as means of information in the retail supply chain.

3.4 Digital model-driven retail supply chain management

According to [Ferne and Sparks \(2014\)](#), the most critical element in retail supply chains is to gather, disseminate, and make demand data visible and used in the upstream actors of the supply chain. Data gathering on product levels and movements facilitate supply chain visibility of the data and enable more accurate steering of the retail supply chain operations. Such data are especially useful in conducting availability improvements for better-ensuring shelf availability and healthy stock levels.

[Ferne and Sparks \(2014\)](#) state that data have become the “lifeblood of retail supply chains”, but there are difficulties connected to the data as well. Primarily, there is an overload of data which is difficult to handle unless appropriate systems are in place, especially in recent times where big data has emerged as a concept. Furthermore, new technology and systems introductions can be disruptive to existing business models. An example of this disruptive effect was claimed by one of the case informants in Paper I, who implied that matching of digital models would disrupt their current business model which relied on tacit knowledge.

This research deals with digital model-driven retail supply chain management, which is the title of the thesis. However, so far, *management* has not been mentioned, instead, the thesis has referred to retail supply chains instead of retail supply chain management, why an explanation is appropriate.

In this thesis, a digital model-driven retail supply chain is a supply chain that contains a retailer that uses digital models of products and customers and matches these to be able to match supply and demand. Digital model-driven retail supply chain management is a collective term for the management of these digital model-driven retail supply chains.

Next, the theory of performance frontiers is presented. The theory of performance frontiers addresses factory performance and trade-offs ([Schmenner and Swink, 1998](#); [Vastag, 2000](#)) and is in this thesis used to promote how the use of matching of digital models can shift the performance frontiers in retail supply chains.

3.5 Theory of performance frontiers

The theory of performance frontiers addresses factory performance and trade-offs across factories. The theory builds on two essential laws, namely, the

law of trade-offs, and the law of cumulative capabilities, which have roots in manufacturing strategy literature (Skinner, 1996; Ketokivi and Salvador, 2007).

The law of trade-offs holds that neither of the performance dimensions (e.g., product quality, flexibility, delivery, unit cost) can be reached simultaneously.

The law of cumulative capabilities holds that improvements in some manufacturing capabilities, such as quality, are basic and facilitate improvements in other manufacturing capabilities, such as flexibility, delivery, and unit cost.

The two laws can, at a first glance, be thought of as two conflicting laws, but they are not. Regarding the law of trade-offs, according to Skinner (1996), a factory can be described as a technologically constrained entity. The choices made by the factories in regard to technologies define the constraints on the manufacturing capabilities. The constraints force trade-offs to appear among the performance dimensions, at least in the short run (Schmenner and Swink, 1998; Skinner, 1996). In the long run, factories which focus their effort on achieving excellence in one, or a few, selected performance dimensions will perform better on those dimensions than factories which focus on achieving excellence in multiple dimensions of performance simultaneously (Skinner, 1974).

Regarding the law of cumulative capabilities, it suggests that improvements in performance dimensions are most effective if the improvement efforts are pursued in a specific sequence, e.g., quality is regarded as a precursor to cost reduction. The law of cumulative capabilities states that certain performance dimensions drive other performance dimensions and holds for a factory in the long run (Schmenner and Swink, 1998). Schmenner and Swink (1998) make a clarification about the two laws and that they are not in conflict. The law of trade-offs concerns across factory performance at a fixed point in time. The law of cumulative capabilities concerns performance within a factory over time.

The theory of performance frontiers unifies the two laws. Schmenner and Swink (1998, p. 108) define a performance frontier as “the maximum performance that can be achieved by a manufacturing unit given a set of operating choices”. Schmenner and Swink (1998) lean on economics theory in order to describe the performance frontier as a production frontier. “A production frontier is defined as the maximum output that can be produced from any given set of inputs, given technical considerations” (Schmenner and Swink, 1998, p. 108). In terms of a performance frontier, the *output* constitutes all performance dimensions, such as quality, flexibility, delivery, and cost. *Technical considerations* constitute the choices that influence the design and operations of a factory (Skinner, 1996).

As a result, there are two types of performance frontiers. The first is an asset frontier which is made up of investments that typically appear as a fixed

asset on the factory's balance sheet. The second type of performance frontier is the operating frontier which concerns the choices that can be made in regard to production, given the set of assets available (Schmenner and Swink, 1998). Vastag (2000) argues that the operating frontiers of companies represent unique resources. These resources "are more important than the asset frontiers in achieving a competitive advantage because these unique resources are valuable, rare and specific to a given firm, and they are difficult to replicate" (Vastag, 2000, p. 353).

Figure 3.2 shows the operating frontiers of two plants (A and B). Both plants share the same asset frontier, which means that they have similar technologies (production equipment) and physical assets. The operating frontiers are bounded by the management policies and procedures undertaken in the plant (Schmenner and Swink, 1998). The asset frontier can, therefore, be said to constitute the ultimate performance that can be achieved by a plant, whereas the operating frontier is the best performance achieved given by how management decides the production to be. In Figure 3.2 both plants are acting on their operating frontiers, but it could be that a plant suffers from waste or inefficiencies that hinder it from acting on the operating frontier.

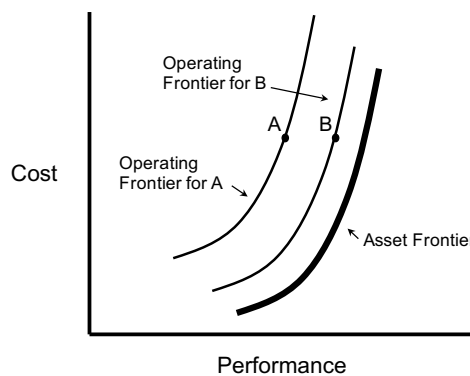


Figure 3.2: The theory of performance frontiers, operating and asset frontiers, a reproduction from Schmenner and Swink (1998). Plant A and B share the same asset frontier, which means that they use similar technology and physical assets. Plant A, whose operating frontier is further away from the asset frontier, likely operates under the law of cumulative capabilities. The operating frontier of plant B is closer to the asset frontier, which implies that plant B likely is subject to the law of trade-offs.

Schmenner and Swink (1998) distinguish between two types of frontier movements, i.e., improvement and betterment. These two movements are shown in Figure 3.3. Improvement concerns removing inefficiencies such that the plant increases its performance and acts on its operating frontier. In Figure 3.3, this movement takes plant A to a new position (A_1) on its operating frontier. Betterment is when the operating frontier is moved closer to the asset frontier. Such movement occurs when the operating policies and procedures are changed to the better. In Figure 3.3, this movement takes the plant from position A_1 to a new position on its bettered operating frontier (A_2). Schmenner

and Swink (1998) further state that once a betterment has been achieved, improvements can start anew. The asset frontier is movable as well but comes to a larger cost compared to moving the operating frontier. Radical technology upgrades or replacements enable movement of the asset frontier. Betterment is, e.g., just-in-time and cell production, i.e., new manufacturing policies and procedures.

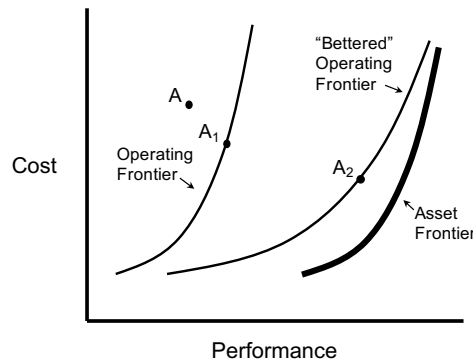


Figure 3.3: The theory of performance frontiers, the bettered frontier, a reproduction from Schmenner and Swink (1998). Plant A does not operate optimally, there are inefficiencies in production. By engaging in improvement work, the plant resolves the inefficiencies and start acting on its operating frontier (A_1). By changing the operating policies and procedures, the plant starts acting on a bettered operating frontier (A_2). Here, the plant's technology and physical assets begin to affect its performance.

A factory faces trade-offs among performance dimensions and is constrained by its operating and asset frontiers. The constraints are decided by the factory's operating policies and procedures as well as physical assets. Schmenner and Swink (1998) exemplify that increasing the product range produced at a factory is likely to increase the average unit costs if operating policies and physical assets remain the same. A change to production cells or factory focus could move the operating frontier such that the increased unit cost would be absorbed by the betterment.

4. Methodology

In this chapter, the research methods used in the appended papers are described and motivated.

4.1 Research process

The research in this thesis began in August 2016. The formulation of the research project was already set upon starting date since it was an approved research application by The Swedish Retail and Wholesale Council. The research project, digital-model driven physical retail and supply chain management, was formally standalone from external parties, which gave the researcher full control of which parties to include later on as the project progressed.

The first couple of months were spent on reviewing literature in the field. Reviewed literature spanned operations and supply chain management literature to retail operations literature. In parallel with reviewing extant literature, an extensive review was performed on real-life retail practices to find out if the novelty of this research holds true. It was found that digital product fitting to some extent is present in the footwear industry, but digital product fitting as a concept for managing supply and demand is not documented in operations and supply chain management literature. The review of real-life practices as well as literature has been ongoing throughout the research in this thesis.

In April 2017, the first study was finalized and presented as a paper at the NOFOMA conference in Lund, Sweden. It was suggested that the paper scope was split in two, so the first study came to focus on the conceptualization of the operational practice and generic functionalities that enable it. The supply chain outcomes were further developed and analyzed in a second study. The second study took a slightly different form after the scope split and was presented at the NOFOMA conference 2018, this time held in Kolding, Denmark. After the split, the second study also included the contextual fit of the operational practice. The two studies were worked on in parallel and were submitted to journals in early and mid-summer in 2018. After both journal submissions, a third study was designed.

During the second half of 2018, a third study was performed. The third study was a case study of two cases that use the operational practice. The study results are presented in the third appended paper with a focus on mechanisms driving the supply chain outcomes, and which contextual factors that influence the mechanisms. In parallel with the third study, the synthesis of the papers was worked on. The synthesis included putting the three papers in relation to each other by applying the CIMO framework. The synthesis addresses the purpose of the thesis by analyzing how the operational practice is used in the two cases from the third study to move the performance frontier.

By the shift of years 2018/2019, the digital model-driven physical retail and supply chain management project ended. This thesis is, therefore, the concluding work of that project. A new research project was approved by VINNOVA with a starting date in November 2018. The new project is titled Platform-based digital shoe retail and involves setting up a pilot where the operational practice will be field-tested. The new project is not part of this thesis but will lay the foundation for the continuing research. The research process thus far is shown as a timeline in Figure 4.1.

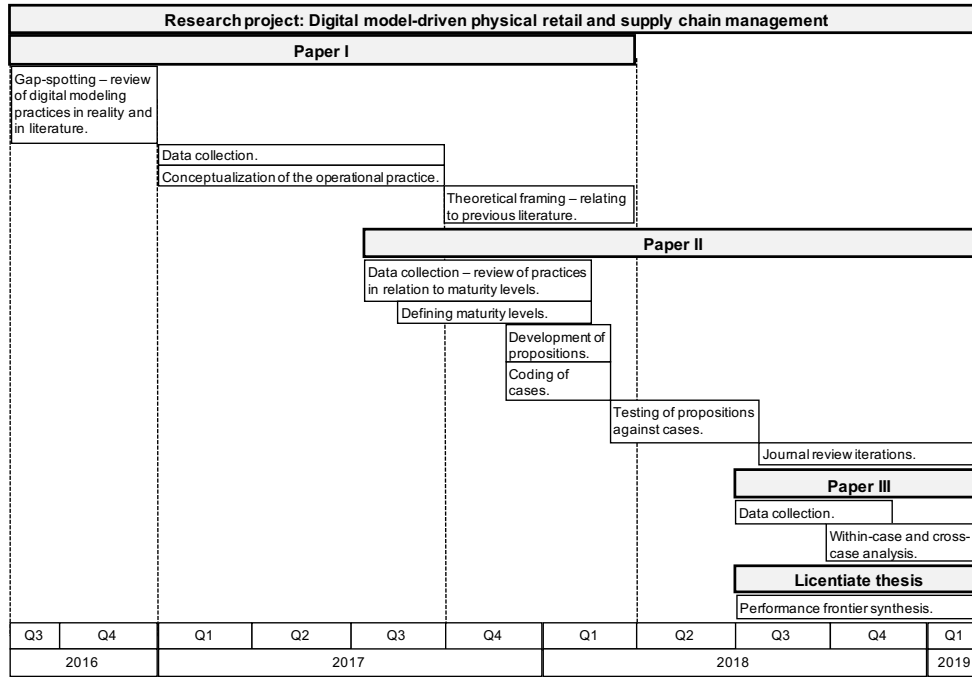


Figure 4.1: Timeline of the research process.

4.2 Research phenomenon

The phenomenon in this research is the interface between digital product models and digital customer models, how these can be matched and located in existing product variety already available in the vast product supply. There is little literature on this interface that outlines which outcomes such interface would have on retail supply chains.

This research occurs in the natural environment of the studied phenomenon, i.e., not in a laboratory or any artificial environment. For capturing the research phenomenon, a design science approach is used to develop an operational practice. Design science research has been linked to the ontology of constructivism (O’Keefe, 2014). The operational practice is a construct of reality, and reality consists of practical effects.

The practical effects comprising the research phenomenon are: low productivity in regard to customer specific production, make-to-stock production lacks customer orientation, matching and digital models exist as a technologies, etc.

By studying this phenomenon, an operational practice, or “artifact” as the literature denotes it as, is constructed in order to solve for the research problem. [Holmström et al. \(2009\)](#) denote such artifact as a solving of a practical problem. In this case, the practical problem is comprised of the operational challenges arising from the mismatch in supply and demand.

4.3 Research design

The research design used in this thesis is a design science approach combined with case research ([Holmström et al., 2009](#)). The chosen research design was selected due to its innovative and explorative nature. Innovative implies that the operational practice does not exist in its fullest extent, and explorative implies that speculations and guesses are necessary to conceptualize the operational practice. The conceptualization phase of the operational practice, therefore, required proposals on how such an innovative practice could solve the research problem of bypassing the efficiency-responsiveness trade-off. Here, it is beneficial to use case research in combination with design science in order to fully understand the developed operational practice.

Against the backdrop of the previously presented research phenomenon, the use of case research is motivated by the following three criteria ([Voss et al., 2002](#), p. 197):

1. “The phenomenon can be studied in its natural setting and meaningful, relevant theory generated from the understanding gained through observing actual practice.”

The first list item is the main reason why case study research was used in all three appended papers, where the actual practice is studied. The cases used in Paper I and III used the operational practice to some extent. In Paper I, meaningful and relevant theory generated from the understanding obtained through observing the use of the operational practice contributed to the conceptualization of the operational practice. Meaningful and relevant theory, here, is an understanding of how the operational practice was used by the cases. In Paper III, observing the use of the operational practice contributed to understanding which mechanisms that trigger supply chain outcomes. As for Paper II, observing actual practice in the form of a case survey enabled the maturity model development since a large number of cases could be surveyed which contributed to an understanding of each maturity level.

2. “The case method allows the questions of why, what and how, to be answered with a relatively full understanding of the nature and complexity of the complete phenomenon.”

The second list item is perhaps the most dominant reason as to why it was chosen to use case research in Paper II and III, namely, to capture a *relatively* complete understanding of the research phenomenon. Relatively is emphasized since the research in this thesis is based on real-life practices that exhibit parts of the operational practice. It still remains to study the fully implemented

operational practice before it can be claimed that a complete understanding of the operational practice has been obtained.

3. “The case method lends itself to early, exploratory investigations where the variables are still unknown and the phenomenon not at all understood”.

The third list item primarily motivates why case research was used in Paper I, i.e., in order to understand the phenomenon of matching digital product and customer models and how it could be used for solving the cost-delivery performance trade-off.

The drawback of studying the already existing is that reality is studied based on historical data and what has happened has already happened. This research, therefore, has a more pragmatic approach. In this research, current practices of emerging product recommendation technology are studied. The practices partly represent the operational practice, why it is beneficial to extract knowledge from such implementations in order to understand implications before they happen.

In order to understand implications before they happen, inductive reasoning has been used. Inductive reasoning allows researchers to think rationally and encourage cognitive reasoning outside the box in order to generate theory. In this thesis, cognitive reasoning outside the box implies that the researcher logically can come up with a possible solution (i.e., the operational practice) to a problem (i.e., the production cost-delivery performance trade-off), which in later phases is supported by theoretical and empirical evidence.

Inductive and abductive reasoning is typically used in design science research because a creative thinking process is needed (Lee et al., 2011). Inductive reasoning was used in Paper I and II which called for a creative thinking process. As for Paper I, the research began with reviewing customization practices and digital modeling practices to first come up with a satisficing solution to the trade-off problem. Then, real-life implementations of such solutions were searched for. No such solution was found in the surveyed implementations, but the footwear industry had similar practices. The creative thinking process is, therefore, characterized by *cherry-picking* of the theoretical solutions to provide products efficiently and responsively, and technology used in real-life applications.

Inductive reasoning seeks to find explanations to empirical phenomena in the social world which present theory cannot explain. Present theory in operations and supply chain management has yet not provided a way to bypass the production efficiency-responsiveness trade-off. Research in the field typically deal with balancing of the trade-off, i.e., to find an appropriate level of efficiency and an appropriate level of responsiveness, however, improvements in one come to a cost of lower performance in the other. The conceptualization process of the operational practice has been highly iterative and has implied going back and forth between literature pertaining to how to solve the

trade-off and which digital modeling practices that are available to solve the trade-off.

Abductive reasoning enables the search for a satisficing solution to a practical problem that the operational practice aims to solve (Lee et al., 2011), but it is legitimate to extend this to inductive reasoning as well. Looking for the satisficing solution is, rather than the optimal solution, beneficial when studying something new that has not been researched. It allows for early development which can be further researched upon the establishment of the initial operational practice.

The research design applied in this thesis is of qualitative nature and is shown in the framework by Maxwell (2013) in Figure 4.2.

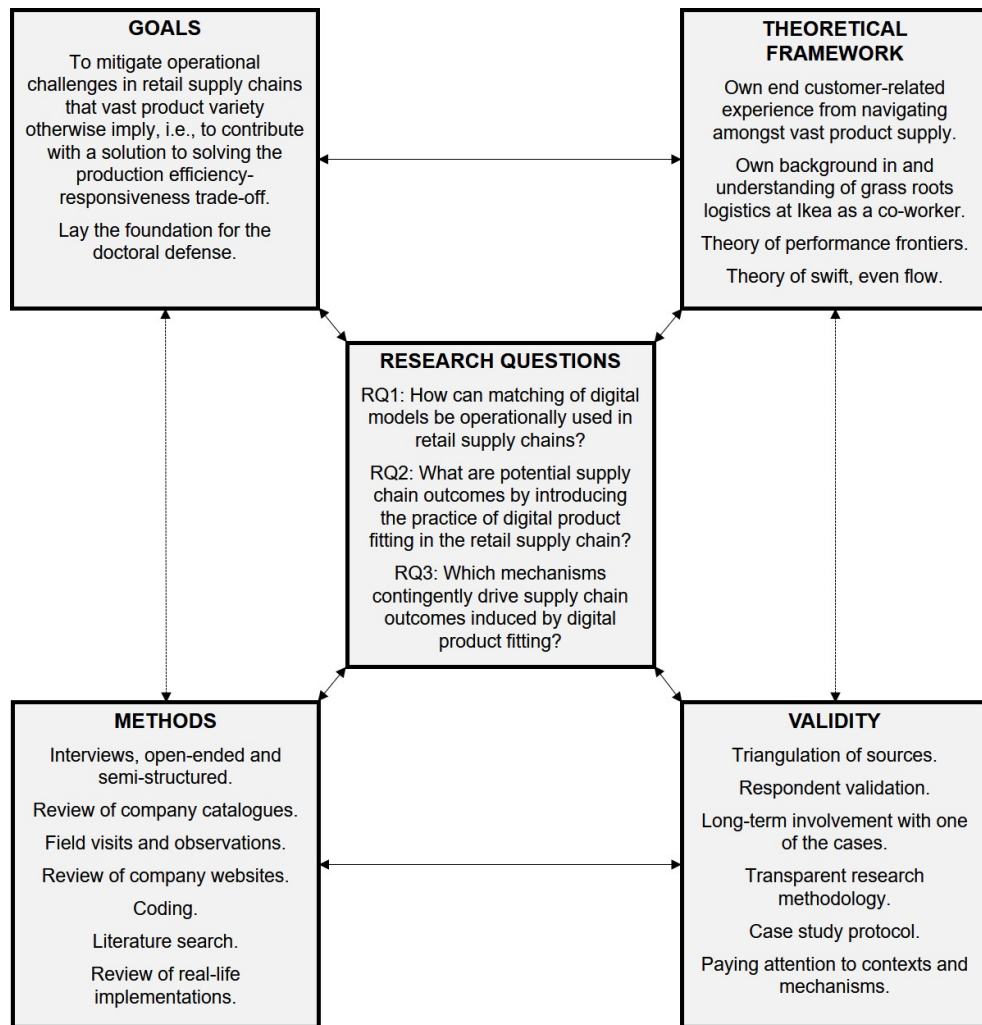


Figure 4.2: The research design of the thesis.

The research design model developed by Maxwell (2013) consists of five interactive components, namely; goals, conceptual framework (here, “theoretical framework” to avoid confusion with the CIMO framework), research questions, methods, and validity. The components are denoted as interactive because qualitative research designs typically need to be constructed and re-

constructed, which implies going back and forth between the components and reconsider their fit to one another (Maxwell, 2013). In compliance with the general research process towards a doctoral defense, this process has not been linear, but rather has taken different turns. The goal of mitigating the operational challenges occurring from the vast product variety in retail supply chains has been the rigid point of focus in reconsidering the research questions, methods used, and theoretical framework.

The most reconsidered components have been the research questions and the theoretical framework. Presenting the research idea and papers at international conferences and seminars at the department have been fruitful in developing skills to communicate the research problem. The first journal submission provided much positive feedback and raised significant insight for the research problem and framing of the research. The probably least reconsidered component has been the methods. Not surprisingly, because it is an emergent practice that is being studied, and the most suitable methods conform to those that are typical for case research and design science. The drawback of studying an emergent practice is the scarce empirical data available to support it, but that is also what makes the research original. Finally, at the point of compiling this thesis, the research design is outlined as shown in Figure 4.2.

The scarce available data from the theoretical framework pose validity threats to the research, especially whether the research holds true if there is little evidence to support it. A contextual factor relevant to this research is what Maxwell (2013) denoted as a thought experiment, which Lee et al. (2011) denote as creative thinking. Thought experiments, here, imply that “bits and pieces” of the theoretical framework were put together conceptually to form a solution to the research problem. The “bits and pieces” are fragments of the operational practice and their effectiveness to solve the research problem is established in the literature, but what is not yet established is the combined use of them, which the papers aim to contribute with. Other contextual factors influencing the interaction between the components are personal experience, and funding and funder goals (Maxwell, 2013). The two factors are reflected upon in the data analysis section and research ethics and bias section, respectively.

The research design in this thesis is comprised of the design science research approach combined with case research. Design science research is used to conceptualize the operational practice, and case research is used for studying the phenomenon in-depth, but also for studying the practice on a more holistic level in form of a case survey.

4.4 Research approach

In line with the purpose of the thesis, to increase the understanding of how matching of digital models of products and customers can be used to shift the performance frontier in retail supply chains, several methods can be applied. Mathematical modeling and simulation could address and quantify var-

ious relations between the operational practice and its outcomes. However, such methods rely on the existence of the phenomenon, or at least a more thorough understanding of the phenomenon in order to model it. The current topic does not exhibit those characteristics, but these methods would be suitable when more research has been done in the area. Experiments could be conducted at the sites of the users of the operational practice, however, this method, too, relies on a more thorough understanding of the phenomenon under study. Current research about the operational practice is scarce and the need for more research is more in line with conceptualizing the operational practice and how it results in supply chain outcomes. Another method to use is survey research, however, like the previous methods, it requires the existence of the phenomenon.

From the above, it seems that methods of case research and case survey in combination with design science at this stage of this knowledge area are adequate to address the purpose.

Design science research has been proposed as an approach for developing innovative operational practices (Holmström et al., 2009). The approach has in operations and supply chain management research often been combined with case research in both the early development phase (Öhman et al., 2015) and later phases evaluating and theoretically elaborating innovative practices (Tanskanen et al., 2015). However, the approach used in this thesis is *design-oriented*. Design-oriented, here, implies that the intention is not to develop an intervention, therefore, the thesis refers to an operational practice instead of an intervention. The intention, however, is to lay a foundation for developing the operational practice into an intervention, but this will be done in the following research project. To lay the foundation, the focus is on studying the already existing related to the operational practice. The operational practice can hence be referred to as a prospective operational practice.

Design science research is further supported by Sandberg and Alvesson (2011), who emphasize that this approach differs when it comes to contribution. It does not follow the ordinary gap-spotting techniques which typically identify a rather narrow research gap. Instead, Sandberg and Alvesson (2011) imply that this type of research claims a broader and more conceptual contribution to science. However, in this thesis, it is also possible to identify a research gap in the literature. There are much literature on matching supply and demand through production productivity, supply chain configurations, and product variety management strategies, but less so on how to take full advantage of the existing product variety in the already produced product supply.

Schwarz and Stensaker (2014) claim that research has fallen into a theoretical straightjacket. They argue that there is an obsession with theory and that theory-driven research has a narrow-minded perception of what is considered scientific contribution. It is claimed that the theoretical straightjacket may inhibit the development of knowledge about organizational change since organizational research most often focus on contributing to a specific and already existing theory (Schwarz and Stensaker, 2014). Theory-driven research is

challenged by taking off the theoretical straightjacket and instead engage in phenomenon-driven research. Phenomenon-driven research aims to go beyond small advancements in theory in order to contribute with new knowledge (Holmström et al., 2009; Schwarz and Stensaker, 2014).

The research in this thesis complies with the above argumentation in the following way. It does attempt to go beyond small advancements in theory by being phenomenon-driven, but that does not limit its ability to contribute to already existing literature, such as the theory of performance frontiers. This thesis contributes with new knowledge, which is in line with phenomenon-driven design science research. The new knowledge is an increased solution space for solving the trade-off between cost performance and delivery performance. It is debatable what *new* knowledge implies, but against the previously presented explanation, new knowledge would imply going beyond small advancements in theory. This research goes beyond small advancements by introducing a novel way of thinking about production productivity and how to efficiently provide products for the individual customer need.

4.5 Case selection

Case research is multifaceted and can be used for many reasons. All three papers use some type of case research, the purpose of the case research is accounted for in Table 4.1.

Cases are chosen because they exhibit interesting characteristics, such as being unusually revelatory, extreme exemplars, or carrying research opportunities (Yin, 2014). The phenomenon under study is emergent in nature and the operational practice is still rare in industry, why there is scarce empirical data available to study. The case selection approach in this has been to study technologically mature applications of the operational practice. As this research began from scratch, with no previous own experience or knowledge about what the operational practice implies, it naturally follows that cases in Paper I are not as mature as cases in Paper III, when more cases have been discovered during the research process.

Mature implies that the cases use the operational practice close to its conceptual formulation, which implies that there are digital models of both customers and products and that computer software is used to find a match between the digital product and customer models. Already in the early study phase of the operational practice it became evident that there are different levels of maturity prevalent in real-life, and less mature applications trigger value in retail supply chains as well.

Table 4.1: Case research applied in the appended papers.

Paper	Case research	Purpose with the chosen case research
Paper I	Case study of three cases	For understanding how the cases worked with the four solution elements of the generic design, and to understand how the generic design would function in real-life. The cases were also used for developing a design proposal based on how the cases worked with the four solution elements. The design proposal and generic design were modified, drawing on further case insights.
Paper II	Case survey of 13 retail cases and three technology developing companies	Since the operational practice does not exist in its fullest form, it was not possible to base potential outcomes on the fully implemented practice; therefore, it was deemed suitable to construct outcome propositions based on covered literature and then analytically test (Yin, 2014) the propositions against identified retail practices in a case survey.
Paper III	Case study of two cases	The two chosen cases use the operational practice on a sufficiently high level on the maturity model developed in Paper II. The cases are analyzed in a within-case and a cross-case analysis for understanding why the operational practice triggers value in the two contexts.

4.5.1 Paper I

The cases in Paper I vary in regard to technological maturity. Paper I first took a single case study approach of a rather immature case, but in the early study phase of the operational practice, it was still unknown how the conceptualization of the operational practice would evolve. The drawback of using a single case for the purpose of exploring the operational practice is that the practice is heavily influenced by the single case. An awareness of unpredictable opportunities and findings was, therefore, present for exploration purposes. More cases were added as the research progressed for a better understanding of the research phenomenon. For Paper I to answer RQ1 (How can matching of digital product and customer models be operationally used in retail supply chains?), it was deemed adequate to use cases of different maturity levels to obtain a less single-case specific operational practice with wider application potential.

As presented in Table 4.1, the purpose of using cases in Paper I was to understand the operational practice in the three case contexts, and through an iterative process with the cases, redesign the operational practice. The purpose of Paper I is to understand the phenomenon of matching digital product and customer models, i.e., understanding of the constituting parts of the

operational practice and possible outcomes. Paper I lays the foundation for the two following papers, Paper II and III. Case research with a few cases is suitable when describing the existence of a phenomenon (Siggelkow, 2007). However, to case studies' dismay, they do not lay a strong foundation for statistical generalizability. This is acknowledged as a limitation and constitutes the motivation for conducting Paper II, which uses case research in the form of a case survey. However, this research does not attempt to generate statistical generalizability but rather draws on analytical generalizability (Yin, 2014).

4.5.2 Paper II

Unlike in-depth case research of a few cases, case survey research relies on surveying a larger number of cases in order to attain stronger analytical generalizability. The purpose, in this case, was to develop literature-derived propositions on potential supply chain outcomes (Larsson, 1993). Case survey research differs from ordinary case research where case characteristics are emphasized rather than in-depth analysis of the cases themselves (Larsson, 1993; Yin and Heald, 1975). The case survey method is an efficient way of learning about already existing case studies. But as the operational practice is an emerging practice, and not previously documented in research literature as case studies, a variety of secondary and primary sources was used. The choice of doing a case survey instead of a multiple-case study was based on the priority of covering a larger domain of product types. Theoretical and literal replication techniques were used for case selection and are further explained in Paper II.

The case survey method attempts to generalize from existing case studies, but relatively few cases (13 cases) were selected in Paper II for being able to claim that the results are generalizable. However, on an analytical level, the research makes a preliminary contribution in exploring the contextual fit, i.e., for which types of products and supply chains that the operational practice is relevant. Paper II is an exploratory paper which presents potential supply chain outcomes as propositions as an answer to RQ2 (What are potential supply chain outcomes by introducing the operational practice in a retail supply chain?). The propositions were partly inductively developed, and partly literature-derived. *Potential* outcomes imply that the propositions need closer scrutiny in further research with stronger empirical evidence that supports them, which lay the foundation for Paper III.

4.5.3 Paper III

Paper II proposed which potential outcomes the operational practice may result in when introduced in retail supply chains. In Paper III, it was observed which outcomes two selected cases had obtained from the operational practice. That is, in Paper II a pre-understanding of potential outcomes was obtained, and in Paper III, a more thorough understanding of the outcomes was obtained. It was studied why these outcomes occurred in response to RQ3

(How do mechanisms contingently drive supply chain outcomes induced by the operational practice?). Understanding the triggering mechanisms completes the circle of understanding the operational practice as a whole, but with one disclaimer, the understanding obtained is with regard to the context studied, i.e., physical fitting of footwear is the most dominant context.

The two cases in Paper III are both mature applications in regard to the operational practice, but they are different in regard to company maturity. One case is a start-up which produces customized dress shoes, whereas the other case has a long history of producing ice hockey equipment. The first case brought their product recommendation technology into use in September 2018, and the latter case brought it to use in June 2017.

Hence, both cases are in the learning phase of using their product recommendation technology. This poses issues on the empirical evidence that can be obtained from the cases. A hockey case informant explained that they yet cannot see the effect of their scanners since the sell-through data is yet not available. When the sell-through data is available such results will be apparent. Hence, Paper III lays the foundation for a longitudinal study to follow up on the outcomes of the operational practice and to further anchor it in empirical evidence. Paper III does not prove the existence of all proposed outcomes from Paper II but rather proves the ones where empirical data existed. This was the solution for dealing with the lack of empirical data.

4.6 Data collection

Data in the appended papers were gathered through interviews, direct observations, and secondary data on company websites. Up next follows reflections on the opportunities and drawbacks associated with the methods and their adequacy to address the purpose statement of the thesis.

4.6.1 Interviews

Interviews have been the primary data collection method in Paper I and III. The interviews allowed rich data to be captured and facilitated a deeper understanding of the studied phenomenon. Interviews are subject to bias, but to mitigate bias, the interviews were carried out with multiple diverse actors who are highly knowledgeable about the phenomenon studied ([Eisenhardt and Graebner, 2007](#)). In this research, interviews have primarily been carried out with key informants ([Yin, 2014](#)), i.e., people who have first-hand knowledge about the company either through a good overview of the company or expert knowledge in his or her own area of expertise.

Key informant interviews are in-depth interviews with carefully selected experts ([Yin, 2014](#)). Key informant interviews forgo preconceived questions prepared by the researcher. In lieu, such interviews focus on the flow of the conversation between the researcher and the informant. In this research, interview guides with questions were prepared in advance of the interviews at

all occasions. Allowing the conversation to float between topics gives the researcher a good overview of the overall interview topic. The drawback is that the key informant can steer the conversation in his or her favor or interest, but that is also opportunistic since there may be details of interest for the researcher that then surface. For example, the very first interview conducted in this research surfaced two original perspectives of the operational practice. First, that tacit knowledge is the core of businesses relying on selling fitting as a service. Second, since the operational practice intends to make tacit knowledge explicit, it violates the original business model. Such revelatory findings influenced the conceptualization of the operational practice in Paper I, and awareness arose that the practice carries great benefits from a system perspective but could have negative implications for the individual company.

In this research, key informants steered the conversation a few times, but it was not necessarily a problem since the interviews were not time-bound, which allowed the researcher to steer back the conversation to the topic of interest. Interviews were recorded for the most part, which was much effective for letting the researcher focus on the conversation rather than note-taking. Interviews typically took the form of a natural conversation and ended with the researcher going through the interview guide to assure that the questions had been covered during the conversation. Interviews were considered adequate for exploratory purposes. Both Paper I and III are exploratory papers and the cases are studied in-depth. Interviews allowed the cases to be studied in-depth, and this led to an understanding of the studied phenomenon.

4.6.2 Direct observations

Some interviews were combined with direct observations and demonstrations. The field visits included store visits and headquarter visits. The operational practice was in the cases represented by foot scanners with corresponding software which gave product recommendations based on the foot scans generated by the scanners. The cases' practice was demonstrated for a total of five times, yielding good insight into how the product recommendation technology was used at the cases. The field visits were much needed in order to understand current product recommendation practices. The understanding of current product recommendation practices gave input to the design of the operational practice.

The direct observations were of participatory character, which means that the researcher participated by letting the case informants scan the researcher's feet and give product recommendations. By participating, questions on operative and basic functionalities of the product recommendation practices arose. Such questions were, e.g., what determines a match, what the match is based on, etc. When designing the operational practice, the operational functionalities are of particular interest. Thus far, an operational practice has not been developed but has rather been conceptualized on a higher analytical level (Yin, 2014), further research includes to field-test the operational practice, and if

the operational practice should be implemented and tested in real life, it is of utmost importance that the operational functionalities are accounted for. Direct observations and demonstrations were therefore deemed adequate for understanding and designing the operational practice, although the practice to this point is undeveloped.

4.6.3 Secondary data

Paper II is based on a case survey, where case data primarily stems from secondary data on company websites. Case survey research differs from ordinary case research where case characteristics are emphasized instead of deep analysis of the cases (Larsson, 1993). To capture the needed characteristics, it was deemed adequate to use secondary data as the main source of data. Paper II, unlike the Paper I and III, did not require in-depth data, why it was resorted to secondary data to capture the needed case characteristics. The quality of secondary data is questionable, but so is the quality of data obtained from people. Whereas the quality of secondary data lies in the researcher's interpretation of the data, the quality of people-obtained data lies both in the researcher's interpretation as well as the interviewees' own bias. People may restrict themselves in the data they provide due to the presence of the researcher.

The sought case characteristics were of basic character, such that primary data was not needed. The characteristics included very high-level attributes, e.g., variety in terms of fitting practice (customization and matching operations in the supply chain), retail channel structure (physical stores and/or web channel), supply strategy (postponement or speculation), and product type. For cases to be selected, they needed to reveal sufficiently detailed descriptions of the sought characteristics since case survey research relies on detailed descriptions. Against this backdrop, secondary data was deemed adequate for Paper II.

4.7 Data analysis

Here, the data analysis procedures in the three appended papers are described and reflected upon.

4.7.1 Paper I and III

For Paper I, the data analysis was threefold. First, the cases were analyzed through developing case descriptions centered on the operational practice elements (in the paper referred to as *solution elements*). The case descriptions contributed with an understanding of the footwear context studied; how the cases worked with the operational practice elements. Secondly, to understand how the operational practice would function in real-life, a contextualized design proposal was created based on how the cases worked with the elements. Thirdly, the operational practice was modified a few times, drawing on further case insights from having iterated it with the cases.

For Paper III, the data analysis was threefold. First case descriptions were developed centered on product and supply chain characteristics drawn from already existing supply chain configuration frameworks. Second, the two cases were analyzed in a within-case analysis as well as a cross-case analysis. The cases were analyzed according to key contextual factors that influence mechanisms which ultimately trigger the outcomes.

Reflections on details when preparing the empirical data

The data subject to the analysis stemmed from interviews, i.e., an interaction between two people, in this case between the researcher and the case informants. For being able to analyze the spoken data, the recorded interviews were transcribed. The level of detail captured in transcriptions vary for different purposes with the transcription. If it is important to understand the interviewee's perception, it is valuable to transcribe with a very high level of detail, even to the extent such that the atmosphere is captured. For this particular research, the level of detail captured in the transcription was on a researcher perception-basis. By perception-basis, it is meant that each spoken sentence was transcribed with the essence of the perception of the researcher, i.e., the interviews were partly transcribed word-by-word and partly by the perception and understanding attained by the researcher.

Such perception-based transcriptions were strikingly effective when analyzing the interviews. People typically speak in an unorganized manner, i.e., many spoken sentences made little sense if transcribed word-by-word. Most of the interviews conducted were held in Swedish, while a few were held in English. All research material with publication intents was written in English. The bilingual approach made it questionable if it was worth transcribing each spoken word when the quotes in Swedish were to be translated into English. The broken, or grammatically and fragmented, sentences made it questionable how to write up a quote. It was not deemed fit to use bad grammar in quotes although that would have been the case if quotes were literal. Such literal quote-practice would be disrespectful to the interviewees. Nevertheless, a Swedish quote translated to English is not a literal quote either due to the translation. To solve the truth value problem of not having made literal transcriptions (in some sense, having altered truth) and showing respect to the interviewees, the interviewees were asked if the final quote represented their intention and was correctly perceived by the researcher.

The problem of other minds

That the empirical data stemmed from interviews implicates *the problem of other minds*, as inferred by the theory of minds (Premack and Woodruff, 1978). The problem of other minds concerns the philosophical question of whether we can understand others' minds. As much as objective as a researcher aims to be; knowledge, experience, and belief are well-packed in a personal backpack that we carry with us each day. 'We hear what we want to hear' is a saying representing our backpack and preconceived notions about the world.

Our backpack influences observations we make, and here is where the problem of other minds comes into play. If I am informed about data from another person, does that imply that my perception of the data is congruent with the other person's perception of the communicated data?

The question does not entail a simple answer, but some measures can be taken for ensuring that the researcher's perception of the data is, to some extent, congruent with the interviewee's perception. Measures taken in this research have been to follow up on the interviews when uncertainties about a correct interpretation and perception of the data arose. Further measures have been to ask the interviewees to validate statements and parts of the analyzed data and to ask questions that pertain to the interviewee environment. For example, a question pertaining to the interviewee environment was to ask about common topics talked about during the common lunch shared among the employees at the company.

4.7.2 Paper II

For Paper II, the data analysis was fourfold. First, case descriptions were developed centered on dimensions relating to the operationalization of the operational practice and product supply. Second, the cases were coded according to maturity level. Third, the cases were coded according to product fit, and fourth, coded according to supply chain fit.

Case descriptions were mainly based on secondary data from company websites, which poses the question if the perception of the data corresponds to reality. It further contemplates the question if the secondary data, which is written by someone, is true since it cannot simply be validated. The two latter analysis steps conform to coding, which raises the question if the coding was correctly performed by the researcher.

The problem of my mind

The problem of my mind refers back to the problem of other minds ([Premack and Woodruff, 1978](#)), but here, the researcher's perception is in focus and not the mutual perception of the researcher and the interviewee. The coding in Paper II was difficult since the cases' practices differed in the technology used and what the technology was used for. It was, therefore, difficult to map the cases on the developed conceptual model. For example, one case used a scanner for transferring scans of customer feet to an external supplier which manufactures customer-specific insoles. The scanner is not used for matching, but for transferring customer information upstream the supply chain. In the maturity model developed in Paper II, that case acts on the lowest maturity level in regard to technological dimension but acts on the highest level in regard to the supply chain maturity dimension. To assure coding consistency, I discussed the cases and the coding with the co-authors. The discussion helped in maintaining a perspective on the case coding and to keep consistency.

4.8 Research quality

Design science research is different when it comes to contribution as already stated (Sandberg and Alvesson, 2011). The value of the research within the academic discipline of operations and supply chain management is therefore significant since it contributes with studying a new phenomenon, rather than studying the effects of an already existing phenomenon. However, such a statement is not 100 percent correct because all three papers study existing practices to be able to understand how the new operational practice can be developed, implemented, and yield value. Studying the non-existent raises the issue of research quality and rigorousness.

Hevner et al. (2004) present a design science research framework in the information systems domain which seems applicable to the operations and supply chain management domain. The framework shows how relevance and rigor are connected and the framework is shown in Figure 4.3.

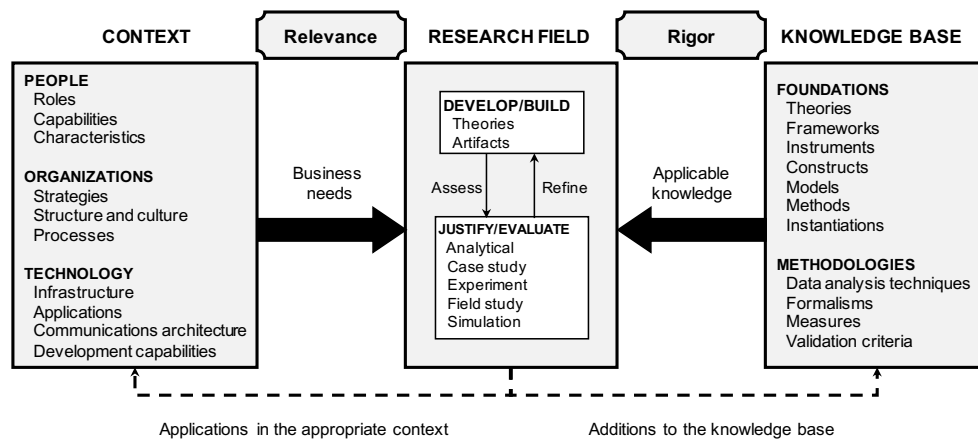


Figure 4.3: A design science research framework, adapted from Hevner et al. (2004). The framework is adapted to fit the notions of the operations and supply chain management domain, i.e., *context* is denoted as environment in Hevner et al. (2004), and *research field* is denoted as IS (information systems) research.

Relevance in the framework by Hevner et al. (2004) implies that the research is driven by business needs. Rigor implies that the operational practice should be assessed in regard to the applicability and generalizability and that it is anchored in existing knowledge and methodologies. This thesis compiles the appended papers and anchors the compiled research in the existing theory of performance frontiers, and the theory of swift, even flow. The research has strong relevance and potential for rigor. Anchoring the research in two highly central theories for operations management is an attempt for rigor. This is further elaborated upon in the next section about pragmatic validity. Since case research is used for evaluating the operational practice, it is appropriate to discuss research quality in terms of construct validity, internal validity, external validity, and reliability (Voss et al., 2002; Yin, 2014). Yin (2014) suggests that internal validity is inapplicable for descriptive and exploratory

research, thus internal validity is disregarded in the exploratory nature of this thesis.

van Aken et al. (2016) state that two important research quality criteria when conducting design science research are pragmatic validity, and practical relevance, both described up next, followed by the traditional research quality criteria of construct validity, internal validity, external validity, and reliability.

4.8.1 Pragmatic validity

Pragmatic validity implies the strength of the evidence claiming that the operational practice will produce the desired results (van Aken et al., 2016). The pragmatic validity is acknowledged as a limitation in this thesis. The operational practice as a whole does not yet exist in reality, therefore, it cannot be established if the operational practice will generate the proposed supply chain outcomes. To this point, evaluation in the field points towards potentially improved retail supply chain operations. Paper III provides evidence for the operational practice in closed supply chains, e.g., transferring the digital customer models to upstream actors brings product development closer to the end-customers. The digital customer models also act as decision support for steering inventory to retailers since the demand planning function knows, from the scanner results, which size and model the customers are.

Finally, although the pragmatic validity is questionable, an attempt for rigor was done by putting attention on transparency of reasoning on both the richly described research design and the analysis of data when defining the operational practice (Ketokivi and Choi, 2014), this was especially important for Paper I which is the most conceptual paper of the three papers, but equally important in Paper II since case survey research is not as common as, e.g., single or multiple case studies. Figure 4.4 shows how the research was performed in Paper I and Paper II in order to illustrate the transparency of the research. The two first phases (problem discovery and design exploration) are dealt with in Paper I, and the third phase of maturity model development is dealt with in Paper II.

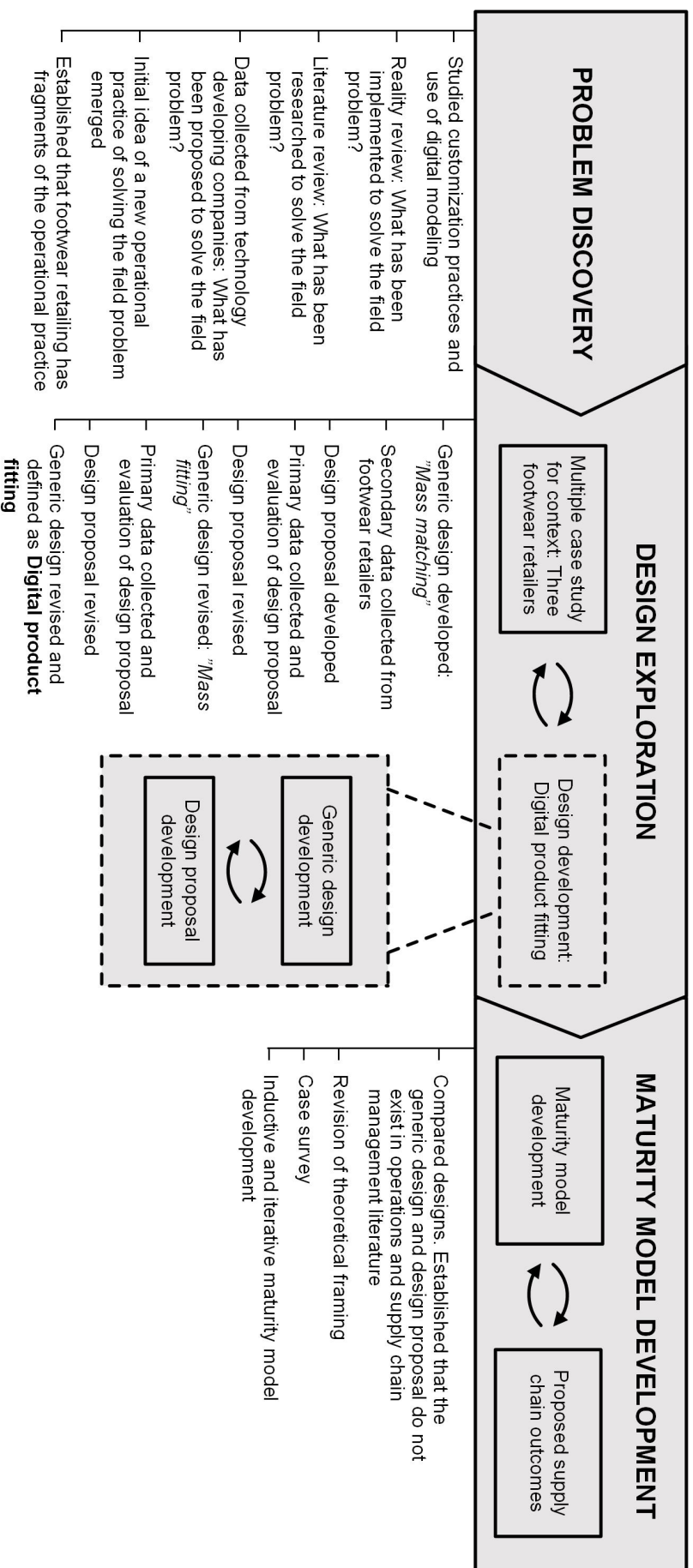


Figure 4.4: How the research in Paper I and II was performed. A reproduction from Paper II.

4.8.2 Practical relevance

Practical relevance relates to relevance in the framework by [Hevner et al. \(2004\)](#) and implies how the operational practice is a valuable contribution for solving a significant field problem ([van Aken et al., 2016](#)). The practical relevance of operational practice in this thesis is established both from theoretical grounding in operations and supply chain management literature as well as from interaction with real-life cases. The research problem of efficiently producing products to specific customer needs has been researched in various ways through operations management practices. Reality shows that the research problem is still a pressing challenge in present retailing, and there is a need for research. The practical relevance is therefore high.

For assessing research quality in relation to case research, the three criteria of construct validity, external validity, and reliability are accounted for below ([Yin, 2014](#); [Voss et al., 2002](#)).

4.8.3 Construct validity

Construct validity implies “identifying correct operational measures for the concepts being used” ([Yin, 2014](#), p. 46). To assure research quality through construct validity, [Yin \(2014\)](#) suggests that multiple sources of evidence are used and that the evidence converge. Convergence is achieved through being able to trace empirical data in time, which typically implies that the data are stored and accessible over time. For this reason, careful attention was put on securing the empirical data through recordings, transcriptions, and case descriptions.

In addition, key informants reviewed drafts of the research in the iterative process for designing the operational practice, which is a measure to ensure construct validity ([Yin, 2014](#)).

4.8.4 External validity

External validity implies “defining the domain to which a study’s findings can be generalized” ([Yin, 2014](#), p. 46). External validity is similar to pragmatic validity, but there is a difference. External validity concerns the generalizability of results, whereas pragmatic validity concerns if the operational practice will produce the anticipated results. External validity can only be valid if the pragmatic validity is valid. The pragmatic validity is acknowledged as a limitation, and so is the external validity. Means taken for ensuring external validity have been to use replication logic in the selection of cases, and to use existing theory and draw on analytical generalizability ([Yin, 2014](#)) to generalize the findings.

4.8.5 Reliability

Reliability implies “demonstrating that the operations of a study – such as the data collection procedure – can be repeated, with the same results ([Yin, 2014](#),

p. 46). For ensuring reliability, or repeatability, Yin (2014) suggests that study protocols and a study database are used. Protocols enable the research to be repeated, and these should be stored and accessible. Case study protocols were used in all papers. Detailed figures, such as Figure 4.4, that describe the research process add to the reliability of the papers, especially when the methodological approach is less known to others.

4.9 Research ethics and bias

This research is funded, which raises the question if the research findings are influenced by the funder. Inevitably, calls for research are to some extent biased since they do point researchers in some direction, i.e., the calls for research represent the interests of the funders. This project, digital-model driven physical retail and supply chain management, was to a beginning a call for research to strengthen the competitiveness of physical retailing, which means that this project would be indirectly influenced by the funder to deal with physical retailing. However, such interest for physical retailing is rooted in inherent advantages that physical retailing possesses, such as capturing customer characteristics in a digital model (cf. matching scanned customer feet with footwear, a practice prevalent in especially Paper I and III).

As already mentioned, this project was formally standalone from external parties, which gave the researcher full control of which parties to include when the project progressed. Hence, this project is not influenced by any external parties.

5. Findings

This chapter presents how the findings from the appended papers answer the research questions. Each paper is guided by either one of the three research questions. Since the research questions in this thesis are comprised of the research questions in the appended papers, the reader is referred to the appended papers for more details; however, the paper findings are repeated here for readability purposes.

5.1 RQ1 – Conceptualization

Paper I answers RQ1:

RQ1 How can matching of digital product and customer models be operationally used in retail supply chains?

Paper I conceptualizes the operational practice as a product recommendation practice that matches digital product models to digital customer models. Paper I dealt with how digital models were operationally applied in four cases of retail supply chains. The paper showed that in order to use digital models operationally, it is crucial that: 1) digital models of customers exist, 2) digital models of products exist, 3) matching needs to be present in order to computationally find matches between digital product and customer models, and 4) add-on manufacturing is needed in addition to existing product supply in case there are no matching products in the supply.

These four aspects can be seen as preconditions for being able to operationally apply the operational practice. The first precondition is important because retail supply chains need explicit knowledge of what products to offer to the customers. This was shown in the paper by, e.g., case Long Tail which offers a broad product range of running shoes to their customers. If retailers have better knowledge of who their customers are, the assortment can be better managed. The long tail assortment is prone to become obsolete, and such products can sometimes be sold back to the vendor but often the products need price discounts for clearance.

Therefore, the second precondition is the prevalence of digital product models. Digital product models are needed in order to make it explicit for retailers what assortment they have in stock how well it matches with customer demand. The third precondition is the prevalence of matching technology, only then can computational matching be operationally performed. The case Matching Customizer shows how computational matching can be used for matching shoe last designs to scanned customer feet. The fourth precondition is necessary to cover for the case when there are no products in the product supply that match customer demand. The case Orthopedics provided insoles to customers, and such add-on practice is shown to be beneficial to cover for the lack of properly fitting shoes.

The paper findings show how the operational practice can be operationally used in footwear retail supply chains in two distinct combinations of speculation and postponement. First, for established retailers (case Long Tail, Orthopedics, and Best Seller), the practice improves responsiveness for mass-produced ready-to-wear products. Second, for start-ups (case Matching Customizer), matching can be used to incrementally introduce make-to-stock production in a responsive build-to-order supply chain.

5.2 RQ2 – Potential supply chain outcomes and contextual fit

Paper II answers:

RQ2 What are potential supply chain outcomes by introducing the operational practice in a retail supply chain?

Paper II proposes potential supply chain outcomes by studying real-life practices which partly use the operational practice. The paper develops a maturity model describing three maturity levels of the operational practice and potential outcomes for each level. Propositions on supply chain outcomes by introducing the operational practice in retail supply chains are proposed and linked to the maturity levels. By analyzing empirical data from a case survey, the findings propose for which context, i.e., product and supply chain, the proposed outcomes are relevant. The findings show that the operational practice would improve performance in material flows, customer relationship management, assortment planning, and new product development.

Material flows

The operational practice is expected to improve material flows through two propositions. Firstly, creating a digital customer model in-store enables retailers to serve customers more efficiently through eliciting customer needs. Store assistants could more efficiently provide customers with fitting products when the customer needs and/or data are made explicit. E.g., such practice at a shoe retailer would be to scan the customer feet and elicit key parameters that are important for the fit of the shoe, such as width and length of the feet. Secondly, the operational practice triggers efficient product flows. Matching of digital product models with digital customer models enables integration of retail channel operations and facilitates the use of customer and product information both in the physical and web retail channels.

A reduction of returns in web retail channels is expected and reduced product handling in both physical stores and web inventory warehouses. Overall, the number of returns will decrease since customers receive a product recommendation and can thus more easily select among fitting products without guessing. Matching enables customers to fit fewer items, and therefore, retail channels can experience reduced product handling, e.g., fewer order lines otherwise occurring when the customer does not know which size to choose

in web retail. In physical retail, store assistants do not need to bring as many sizes to the fitting room when serving customers.

Customer relationship management

Digital customer model-elicited parameters enable retailers to begin selling functions instead of only selling products. Retailers can, hence, engage in more advanced customer relationship management practices and pitch relevant products to the customer base. Many products today are sold on a purely transactional basis, but if retailers have access to digital customer models, they could develop relationship-based sales where a function as a service is sold in lieu of pure transactional sales. Such customer relationship practice can potentially have customer retention effects and new product development according to customer needs can be followed up by a direct sales pitch to the customers potentially benefitting most from a new product. Retailers and manufacturers can also pitch products that are in the process of becoming obsolete to their customer base.

Assortment planning

Digital customer model-elicited parameters enable efficiency in providing a more accurate assortment towards customer demand. Selecting upon the assortment to provide to customers is difficult in physical retailing since the product variety is constrained by the limited shelf space. However, web retailers can practically offer the whole product variety range without compromising long-tail assortment. Retailers can use the digital customer models to select appropriate assortment based on their customers' preferences or needs. I.e., the digital customer models act as decision support for assortment planning.

The operational practice is also expected to trigger the outcome of efficient and responsive long-tail assortment management. Digital customer models support postponement of the final configuration of a product through manufacturing of make-to-order enhancements (e.g., add-ons), as well as enabling retailers to more effectively select the long-tail part of the assortment. E.g., such practice at a shoe retailer is to customize an insole to the shoe to make the shoe fit the customer.

New product development

The operational practice brings value for product development. Digital customer models should be an excellent means for transferring customer information across supply chain actors and can constitute an important aspect of fit-based design of new products. Transferring digital customer models to upstream supply chain actors carries advantages for product development suppliers to align the design of their assortment with customer demand.

The maturity model

The outcome propositions were inductively derived from reviewing real-life practices as well as literature. It became clear that both simpler and more advanced use of the operational practice trigger supply chain outcomes, and thus, a maturity model of the operational practice came to develop. The contribution of the maturity model in regard to the addressed research question (What are potential supply chain outcomes by introducing the operational practice in a retail supply chain?) is that even basic use of the operational practice triggers supply chain outcomes. The reader is referred to Paper II for more details on the development of the maturity model and definitions of the maturity levels.

Contextual fit

Paper II further studies the contextual fit of the operational practice. The contextual fit implies two types of fit. Firstly, how well the operational practice fits different products, i.e., the product fit. Secondly, how well it fits different supply chains, i.e., the supply chain fit.

Findings show how the operational practice is of most relevance for products in which product and customer attributes are easily measurable, and tacit knowledge can be made explicit using digital models of customers and products. The operational practice is further relevant for products where the final product configuration is difficult to postpone. Regarding the supply chain fit, the operational practice is of most relevant for supply chains using automated matching in any type of retail channel supplying speculatively mass-produced products.

5.3 RQ3 – Mechanisms

Paper III answers:

RQ3 How do mechanisms contingently drive supply chain outcomes induced by the operational practice?

Paper III evaluates mechanisms driving the outcomes in two retail supply chains; the efficient make-to-stock supply chain, and the responsive make-to-order supply chain. The results yield an understanding of when certain outcomes are triggered in the two cases. Understanding the triggering mechanisms is essential for being able to control negative outcomes and provoke the positive. The CIMO (Context-Intervention-Mechanism-Outcome) framework is applied for critically evaluating mechanisms that drive supply chain outcomes when using the operational practice in two retail supply chains. The paper analyzes mechanisms according to key contextual factors which influence if the outcomes are achieved or not.

Five mechanisms influence the triggering of supply chain outcomes in the two cases. 1) use digital models to transform tacit knowledge into explicit,

2) local product-customer match, 3) customization, 4) supply chain visibility of product-customer match, and 5) reuse of digital models. The mechanisms emerge from the operational actualization of the operational practice and its maturity in regard to the two cases, Dress shoe customizer and Skates stocker.

Mechanism: Use digital models to transform tacit knowledge into explicit

The mechanism of using digital models to transform tacit knowledge into explicit enables product fitting standardization excellence across franchised retailers, or retailers within the same chain, i.e., the likelihood of the customer being recommended the same product across retailers increase. This mechanism triggers the outcome of in-shop operations efficiency at retailers since store assistants can more accurately provide customers with products.

In the two cases, the implemented foot scanners and product recommendation software drive customer trust, i.e., the customers trust the product recommendation and thus they are prone to buy the recommended product. The outcome of customer trust enhances the reliability of the demand information that can be transferred to upstream supply chain actors who know exactly what the customers look like and also which products they buy.

Mechanism: Local product-customer match

The mechanism of local product-customer match drives the same outcomes as the previous mechanism. The mechanisms share the same outcomes of providing in-shop operations efficiency and customer trust at the retailer due to the implemented product recommendation practice.

The local product-customer match mechanism facilitates product recommendation by the retailers and the customers are convinced about the product recommendation. Being convinced about the recommendation is especially important in the two cases since the products supplied are expensive and the fit is both important and difficult to decide upon by the customers. The mechanism of local product-customer match stems from the operationalization or implementation of the operational practice.

Mechanism: Customization

The mechanism of customization drives the outcome of producing products according to demand, on demand. Digital customer models can be used to extract information about the customer and such extractions facilitate more efficient make-to-order production. Dress shoe customizer considers the expensive physical retailing space as an influential factor for adopting make-to-order production rather than make-to-stock. The make-to-order production strategy adopted by Dress shoe customizer leads to the outcome of having no or little oversupply in their store. This outcome is not achieved by Skates stocker that primarily relies on selling stocked off-the-shelf products.

Mechanism: Supply chain visibility of product-customer match

The mechanism of supply chain visibility of product-customer match implies that supply chain actors can use the product recommendation of the operational practice to plan their operations. For retailers, the product recommendation brings positive outcome in deciding upon which assortment and product variety to stock in the store, and for manufacturers, the digital customer models and product recommendation brings positive outcome in new product development.

The contextual factor underpinning the presence of the supply chain visibility mechanism is frequently new collections for make-to-stock products since they face the risk of obsolescence from oversupply.

Mechanism: Reuse of digital models

The mechanism of reuse of digital models is a trigger for more integrated omnichannel value creation. Customers could use their 3D models created in the physical store for online product fitting and repeat sales at the cases' web shops. An integrated omnichannel enables presentation of a larger assortment to the customer compared to single channel retailing.

The most distinct mechanism in the efficient supply chain is that of supply chain visibility of the product-customer match. For the responsive supply chain, the operational practice especially triggers value in providing fit excellence for custom-made products, while simultaneously improving manufacturing efficiency. Matching to last design in the responsive make-to-order supply chain enables fit and manufacturing efficiency excellency.

6. Shifting the performance frontier

Previously, companies which are shifting from heavy use of inventory to match supply with demand have been focusing on mass customization (Piller and Kumar, 2006). However, introducing the operational practice to match supply with demand increases the solution space. By using matching technology, it is possible to change the cost-delivery trade-off to achieve both efficiency and responsiveness in the supply chain, achieving much of the customization benefits at a lower production cost, and this would lead to a major shift in the performance frontier.

Literature often suggests that production efficiency is associated with lean production through reduced buffers, reduced lead times, and reduced demand volatility (Yin et al., 2017; De Treville et al., 2004; Hines et al., 2004). However, in retail supply chains, it is extremely challenging to reduce demand volatility for many types of products, especially the innovative products with a considerable shorter life-cycle than bulk, or functional, products (Fisher, 1997). Fisher (1997) suggests that the supply chain configuration should be designed to the nature of demand of the products that it supplies.

As was found in Paper I, the operational practice does not entail a choice between designing efficiency and responsiveness capabilities in supply chains, but rather allows the combination of efficiency and responsiveness capabilities in the *same* supply chain to drive market mediation performance. De Treville et al. (2004) suggest that lead time reduction should be used to improve market mediation performance. Lead time reduction complies with this research in achieving responsiveness in delivery to end-customers, as well as achieving production efficiency. What distinguishes this research is the use of technology (i.e., matching of digital models of products and customers) to drive efficiency and responsiveness.

Paper II develops a maturity model describing three maturity levels of the operational practice. There are two maturity dimensions, a technological maturity dimension, and a supply chain dimension. It is mainly the most advanced, or top, maturity level that has the power to shift the performance frontier, where the technology outputs information-rich digital models and accurate product recommendations, and when the output is streamlined across supply chain actors to better align supply with demand. From Paper II, two cases came to be particularly interesting for shifting the performance frontier. Paper III is based on these two cases labeled *Dress shoe customizer* and *Skates stocker*, and the labels are kept in the analysis in this chapter. The reader is referred to Paper III for more detailed case descriptions since only key characteristics of the cases are presented up next.

6.1 Key characteristics of the cases used for argumentation of a performance frontier shift

The cases combined are of particular interest in shifting the performance frontier. Dress shoe customizer is a dress shoe retail supply chain producing customized dress shoes. Skates stocker is an ice hockey equipment retail supply chain big on mass-produced skates. Both cases use foot scanners in order to create digital customer models, and corresponding software recommends fitting footwear from their assortment to the customer.

Table 6.1: Cross-case analysis of Dress shoe customizer and Skates stocker. A reproduction from Paper III.

	Dress shoe customizer	Skates stocker
Complexity	Less complex	More complex
Fitting practice	Match to last design	Match to stock
Supply strategy	Make-to-order	Make-to-stock
Maturity of matching technology	Complete contour data	Key measures from complete model
Product type	Fashion, the design is superior to the fit	Sports, performance is superior to the design

Table 6.1 shows the main differing characteristics of the cases. Dress shoe customizer technologically acts on the top maturity level using complete contour data of the digital customer model to match this to digital last designs upon which the dress shoes are made-to-order. Skates stocker technologically acts on the mid-maturity level since only key measures of the digital customer model are used for matching customer feet to make-to-stock produced skates to be sold off-the-shelf.

Supply chain integration-wise, Dress shoe customizer is difficult to map into the maturity model since their supply chain is of less complexity compared to that of Skates stocker. The supply chain of Dress shoe customizer only spans a retailer and a factory producing the shoes. Dress shoe customizer has their last design operations in-house, and only communicates the orders with the factory, and does not communicate other types of information regarding, e.g., product development.

Skates stocker, on the other hand, is a big company, even one of the market-leaders on selling skates, and has a more complex supply chain with many actors and headquarter functions. The scanner, therefore, provides upstream actors with valuable downstream information about the customer that otherwise could be difficult to obtain, and Skates stocker has taken advantage of

this opportunity. Although sell-through data is yet incomplete for the purpose of evaluating the scanners' effect on the retail supply chain operations, such as inventory levels, the scanner data will be used for new product development when the next collection of skates will be launched. Skates stocker is, therefore, more mature when it comes to supply chain integration compared to Dress shoe customizer, even though Skates stocker acts on a lower maturity level technology-wise.

In regard to the two cases' maturity, the operational practice in this thesis entails the idea of using the information-rich technology used by Dress shoe customizer, but to streamline the information to upstream supply chain actors as done by Skates stocker. These differences make the combination of the two cases particularly interesting.

One major theory in operations management is especially useful for the purpose of this thesis, i.e., the theory of performance frontiers, first appearing in [Schmenner and Swink \(1998\)](#), and later in [Vastag \(2000\)](#).

6.2 The theory of performance frontiers

The theory of performance frontiers originally stems from manufacturing strategy literature; however, in this thesis, the scope of performance frontiers is extended to apply to retail supply chains rather than manufacturing plants to fit the research purpose. Such extension seems legitimate according to [Vastag \(2000\)](#) who extends the theory of performance frontier to include a "between-firm" scope rather than the original within-firm scope.

The definition of a performance frontier is in this research redefined from the definition by [Schmenner and Swink \(1998\)](#) to include supply chains. Here, the performance frontier is therefore defined by the maximum performance that can be achieved by a retail supply chain given a set of operating choices (cf., the definition by [Schmenner and Swink \(1998, p. 108\)](#): "A performance frontier is therefore defined by the maximum performance that can be achieved by a manufacturing unit given a set of operating choices").

In the context of Skates stocker, they can choose to pursue speculative make-to-stock production with a greater risk of oversupply or shortage of products, or, they could opt for the operating choice of adopting the matching technology (which is currently in use in their retail operations) and thus improve market mediation performance.

Table 6.2 shows how the theory of performance frontiers is extended to this particular research. The context for performance frontier theory is, therefore, on retail supply chain level. The operating frontier is, here, the retail supply chain operations, i.e., how traditional retail is performed today. As for the asset frontier, it is redefined as the *utilization frontier*, implying that available product supply is fully utilized to achieve market mediation performance. Cost, here, includes production costs and supply chain costs for manufacturing and inventory holding. Delivery performance is, here, meant by responsive

market mediation performance, which implies fully utilizing available product supply to match supply with demand in a responsive manner, such that the delivery waiting time for the end-customer is minimized.

Table 6.2: Performance frontiers theory applied to the research context.

	Performance frontier in manufacturing	Performance frontier in retail supply chains using the operational practice
Context	Manufacturing plant	Retail supply chain
Operating frontier	Plant operations	Retail supply chain operations
Asset frontier	Plant design and investment	“Utilization frontier” Physically available product supply
Cost	Production cost within the plant	Cost related to the degree of product variety
Performance	Plant performance	Responsive market mediation performance

For market mediation performance to improve with cost held constant, then technology must be used to move the operating frontier closer to the utilization frontier (Skinner, 1996). Here, technology in form of the operational practice of matching digital product and customer models has been used to move the operating frontier closer to the utilization frontier, as shown in Figure 6.1 and 6.2 in the following section. By using the matching technology, market mediation performance is improved in the two cases since products, to a much greater extent, will be matched to customers in need of them (Fisher, 1997). The small distance between the upward part of the operational practice retail operating frontier and the utilization frontier implies just that. When there is a vast supply of products on the market, and there is technology that maps the product supply, only then is it possible to fully utilize the existing product supply to achieve the highest possible market mediation performance.

6.2.1 Dress shoe customizer

Figure 6.1 shows three frontiers for Dress shoe customizer. The frontier to the left is labeled “Traditional” make-to-order retailing operating frontier and represents how fully customized shoes are manufactured and retailed by a shoe-maker. These “traditional” operations include unique last design and iterative fitting sessions with the customer. The iterative fitting sessions imply that the customer participates in the manufacturing process from an early phase so the shoes upon completion fit the customer. The traditional make-to-order retailing operating frontier does not provide much responsiveness (if any), i.e., the customer has to wait several weeks for delivery of the shoes.

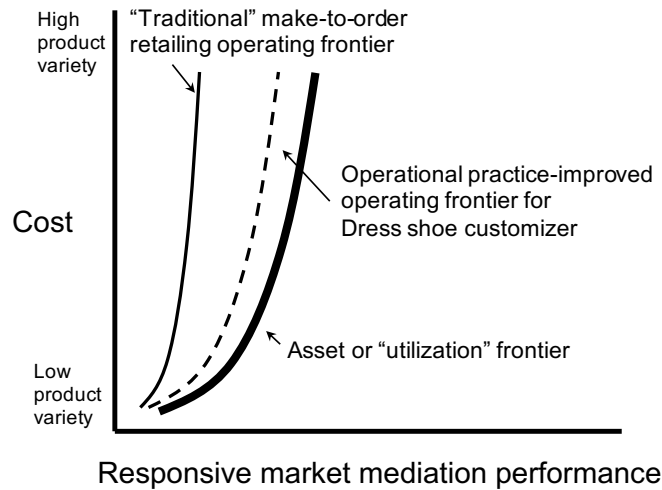


Figure 6.1: Shifting the performance frontier for Dress shoe customizer.

The dashed line represents the operational practice-improved operating frontier for Dress shoe customizer. By using the operational practice to match customer feet to last designs, the manufacturing process will be less iterative with the customer, and therefore, manufacturing will be more efficient. The customer can have the shoes delivered to her within a shorter period of time if the manufacturing is more efficient, thereby shifting the traditional make-to-order retailing operating frontier closer to the asset frontier. The movement of the traditional make-to-order retailing operating frontier depends on the improvement, or betterment, in the manufacturing process triggered by the operational practice.

The thick line to the right represents the asset frontier or “utilization” frontier. However, the utilization frontier is not applicable to make-to-order production since there is no physical product supply available. Instead, the utilization frontier is regarded as the asset frontier as defined by [Schmenner and Swink \(1998\)](#), which means that manufacturing is optimally performed using the investments and technology available in the plant. The operational practice-improved operating frontier does not coincide with the asset frontier because there are most definitely more ways to better the operations of Dress shoe customizer. The asset frontier cannot achieve much responsive market mediation performance since make-to-order by default implies delivery lead times ([Gunasekaran et al., 2001](#); [Gunasekaran and Ngai, 2005](#)).

6.2.2 Skates stocker

Figure 6.2 shows three frontiers for Skates stocker. The frontier to the left is labeled “Traditional” off-the-shelf retailing operating frontier and represents how make-to-stock products are manufactured and retailed. These “traditional” operations include to speculatively produce to anticipated demand. Typically, producing to stock comes with obsolescence from an oversupply of products and lost sales from a shortage of products ([Fisher, 1997](#)). The tradi-

tional off-the-shelf retailing operating frontier provides more responsiveness from shelf availability than the frontier of make-to-stock. In traditional retail, when the customer buys products off-the-shelf, the delivery performance is, here, given by the availability on the shelves. Therefore, when product variety is high, it is more likely that customers will find products that fit their preferences and needs (Brynjolfsson et al., 2003; Chopra, 2018). The responsive market mediation performance, therefore, increases as product variety increases, given that the shelves are replenished. If the product variety is low, the market mediation performance is low.

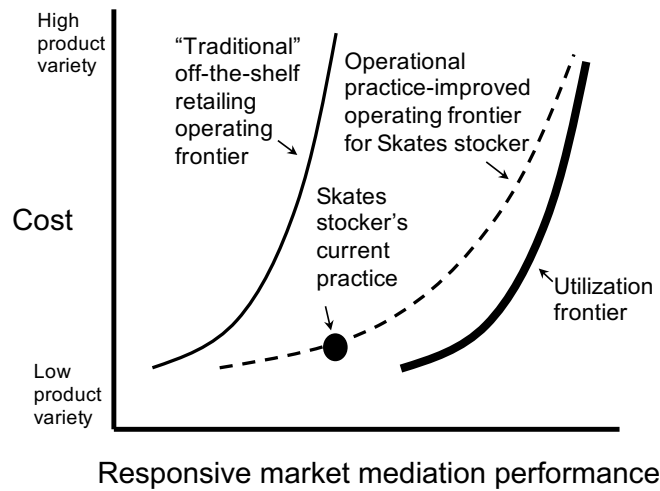


Figure 6.2: Shifting the performance frontier for Skates stocker.

The dashed line in Figure 6.2 represents the operational practice-improved operating frontier for Skates stocker. By using the operational practice to match customer feet to skate family and size, the retailers can more efficiently provide the customer with fitting skates, and upstream actors can better align supply with demand due to supply chain visibility of the scanner results. The movement of the traditional off-the-shelf retailing operating frontier depends on the betterment in the suppliers' control over the assortment and the ability to maintain inventory levels such that neither stockouts nor obsolescence occur. The dashed line tells us that more responsive market mediation performance can be achieved to the same cost as that of the traditional off-the-shelf retailing operating frontier, but the largest gain is achieved when the product variety increases.

Skates stocker has rather low product variety, only three professional skate families, therefore, they act on the lower half of the operational practice-improved frontier. For Skates stocker to advance upward on the operational practice-improved frontier, they need to increase their assortment width a lot, preferably with hundreds of different sport shoe models by collaborating with other retail supply chains. Only when the product variety is high, the operational practice brings the most responsive market mediation performance by matching long-tail products to customers in need of them.

The thick line to the right in Figure 6.2 represents the utilization frontier. The utilization frontier in the case of Skates stocker constitutes of the physically available skates in Skates stocker's supply chain. The operational practice-improved operating frontier for Skates stocker does not coincide with the utilization frontier, just like that of Dress shoe customizer, because there are most definitely other ways to achieve responsive market mediation performance.

The technology radically, and conceptually improves the current retail operations by moving the operating frontier closer to the utilization frontier. What the improvement conceptually implies is elaborated up next in the theory of swift, even flow.

The theory of swift, even flow implies that the more swift and even the materials flow is, the higher the productivity (Schmenner and Swink, 1998). In this thesis, high productivity solely stems from microeconomic theory focused on economies of scales in production, but what economies of scale imply for productivity is not well understood. The theory of swift, even flow, on the other hand, reveals more details on what productivity implies on a factory level.

Regardless of the productivity gain depends on the reduction of non-value added work, reduction of throughput time, or reduced variability as outlined by Schmenner and Swink (1998), what is important in this thesis in regard to productivity is that factories produce using high productivity such that the most output is obtained per unit of input resource (Yin et al., 2017). The ultimate aim of the operational practice is to fully utilize existing product supply that has already been produced in order to combine responsiveness and production efficiency in supply chains. Production is left for producing companies to optimize under the assumption of companies' economic profit-maximization rationality (Ketokivi and Choi, 2014).

Conceptually, swift and even material flows are ideal for the operational practice, however, as companies increase their product range, they are more likely to face difficulties in maintaining swift and even material flows. A wider product range will likely yield an increased unit cost if production policies and technology are held constant, i.e., we are tapping into the law of trade-offs.

The law of trade-offs states that neither of the performance dimensions (e.g., product quality, flexibility, delivery, unit cost) can be reached simultaneously. However, Schmenner and Swink (1998) argue that higher levels of the performance dimensions *can* be reached simultaneously if the operating frontier is moved closer to the asset frontier (here, utilization frontier), and that can only be done through the use of technology that radically improves the current operating frontier. Important performance dimensions in this thesis are delivery performance representing responsiveness and cost performance representing efficiency, and I argue that these can be reached simultaneously through the use of the operational practice. Given that there already is product sup-

ply available on the market, maximum delivery performance is achieved, and given that companies strive for high productivity in the production of products, the available products on the market are produced using high productivity. By matching available product supply to customers in need or want of them, responsiveness and efficiency are achieved without a trade-off between the two.

7. Discussion

This chapter begins by revisiting the CIMO framework, and then discusses how the research question findings address the purpose of the thesis. Next, the contribution and significance of the research findings in terms of the research purpose are highlighted. The chapter ends with a discussion on the generalizability of the research findings.

7.1 Revisiting the CIMO framework

As pointed out in the introductory chapter, this research is comprised of the CIMO framework. The framework provides a complete understanding of the operational practice in the discipline of operations and supply chain management within the framework boundaries. Here, it is shown how the findings from the research questions fulfill the purpose of the thesis. Before explaining how well the research question findings fulfill the purpose, a restatement of the purpose is appropriate.

The purpose of this thesis is to increase the understanding of how matching of digital models of products and customers can be used to shift the performance frontier in retail supply chains.

7.1.1 How the findings from RQ1 address the purpose

The findings from RQ1 (How can matching of digital product and customer models be operationally used in retail supply chains?) expand our conceptual understanding of how digital models of customers and products can be used to make better use of existing product supply in retail supply chains. When the research commenced, it was premised that digital modeling was an effective means to capture information about both products and customers. The premise was confirmed in Paper I and the conceptualization of the operational practice was possible.

The conceptualization of the operational practice in Paper I contributes to, and builds on, previous research on supply chain design frameworks, and particularly, how to design for efficiency and responsiveness in supply chains. Seminal work in the field of supply chain configuration includes, e.g., [Fisher \(1997\)](#) and [Pagh and Cooper \(1998\)](#). The findings show how the use of digital modeling in retail supply chains does not entail a choice between speculation and postponement ([Pagh and Cooper, 1998](#)), or, efficiency and responsiveness ([Fisher, 1997](#)), in the design of the supply chain. Instead, the findings explain how matching of digital customer models and product models allows both efficiency and responsiveness to be combined, reducing the need for modifying products in achieving the objectives of mass customization ([Gilmore and Pine II, 1997](#)). The operational practice, defined and elaborated on, does

not entail a choice between designing physically efficient and responsiveness capabilities in supply chains (Fisher, 1997). Matching allows the combination of physical efficiency and responsiveness capabilities in the *same* supply chain.

7.1.2 How the findings from RQ2 address the purpose

The findings from RQ2 (What are potential supply chain outcomes by introducing the operational practice in a retail supply chain?) expand our operational and contextual understanding of how digital models of products and customers enable supply chains to be responsive and efficient. While the aforementioned findings from RQ1 expand our understanding on a conceptual level, the findings from RQ2 expand our understanding on an operational level, i.e., the findings yield a more detailed explanation as to what efficiency and responsiveness outcomes that the operational practice potentially triggers. The developed propositions in Paper II contributes to various research areas by building on previous research on material flows, customer relationship management, assortment planning, new product development, and information sharing.

Paper II relates to previous work on achieving the customization benefits using mass production efficiency and economies of scale. Seminal work in the field includes mass customization, and how postponement, modularity, and product architecture can be used in order to manage the production efficiency-responsiveness trade-off (Wan et al., 2012). Drawing on the same supply chain configuration frameworks as in Paper I (Fisher, 1997; Pagh and Cooper, 1998), this research complements the frameworks to include more detailed product and customer characteristics. Including product and customer characteristics provides a more nuanced view of the established frameworks. However, no new configuration framework is developed, nor is it theorized how supply chain outcomes truly are achieved by the operational practice. Paper II addresses the purpose of the thesis by elaborating on potential outcomes as a result of how retail supply chain performance is achieved. I.e., Paper II yields a more detailed understanding of what is meant by a shift in the performance frontier in retail supply chains when using the operational practice.

7.1.3 How the findings from RQ3 address the purpose

The findings from RQ3 (How do mechanisms contingently drive supply chain outcomes induced by the operational practice?) expand our understanding of the mechanisms which outline how and when matching of digital models of products and customers drive efficiency and responsiveness outcomes in supply chains.

The operational practice has been conceptualized and potential outcomes have been proposed; however, there is a need to understand the mechanisms for

achieving the proposed outcomes in specific contexts. Paper III is a response to that need. Understanding the mechanisms is of utter importance for understanding why the outcomes occur, especially for supply chain managers to be able to control which outcomes to obtain in a particular context (Jonsson and Holmström, 2016). Paper III primarily builds on the research area of supply chain design and supply chain performance by outlining how outcomes depend on contextual factors given that supply chains are designed differently. Paper III addresses the purpose of the thesis by yielding even more details of when and why the operational practice leads to outcomes given the contextual factors.

7.2 Contribution and significance: Shifting the performance frontier

Revisiting the definition of a performance frontier in this thesis, it refers to the maximum performance that can be achieved by a retail supply chain given a set of operating choices. In relating the contribution of this thesis to various operations and supply chain management research areas, it draws on four main research areas, namely; production capabilities and manufacturing strategy, supply chain design, supply chain performance, and omnichannel. The theory of performance frontiers (Schmenner and Swink, 1998; Vastag, 2000) is used to analyze how retail supply chains can move closer to their utilization frontier through the use of new technology. The operating choices distinguished between are, hence, the current retailing operations versus the operational practice-improved retailing operations. Up next follows how this thesis relates to the four research areas.

Brown and Bessant (2003) imply that if companies attempt to adopt trending manufacturing approaches, such as mass customization, there is a risk that the contribution of factory-specific manufacturing strategies are lost. This thesis promotes that factory-specific manufacturing strategies are kept such that the competitiveness of the manufacturers is kept.

Mass customization has been proposed to mark the end for trade-offs and other competitive priorities, however, that is not the case. A study by Squire et al. (2009) showed that the cost-delivery trade-off remains. This opens up the opportunity for the operational practice to bypass this trade-off. Tan and Vonderembse (2006) showed that computer-aided design usage contributes to new product development performance, which this thesis complies with. The operational practice bypasses the cost-delivery trade-off by allowing manufacturing companies to endeavor high productivity and high quality operations for economic sustainability to remain their market competitiveness in the products produced (Schmenner and Swink, 1998; Ketokivi and Schroeder, 2004). Delivery performance is promoted since the product supply on the market is mapped and the operational practice facilitates efficient navigation of available products on the market.

The operational practice aims at matching already produced product supply to customers in need of it to mitigate market mediation costs as presented by [Fisher \(1997\)](#). Factory focus ([Skinner, 1974](#)), here, implies that the available product supply is produced using high productivity such that the unit cost is the lowest possible ([Schmenner and Swink, 1998](#)). It naturally follows that the operational practice favors make-to-stock production to achieve economies of scale such that the unit cost is the lowest possible.

Hence, the performance measures of most relevance for the operational practice are delivery and cost performance ([Squire et al., 2009](#)). The make-to-stock supply chain should strive for efficiency in production which results in cost performance ([Fisher, 1997](#)). The matching of already available products on the market to customers in need of them means that maximum availability is achieved and that fact results in delivery performance.

The operational practice acts as both a product recommendation system and as an information technology ([Schrage, 2018](#); [Tan and Vonderembse, 2006](#)). Digital customer models are excellent means of information to streamline to upstream supply chain actors such that product development is better aligned with customer demand ([Tan and Vonderembse, 2006](#)). The operational practice can recommend products across marketing channels. Physical retailing is advantageous to capture digital customer models, e.g., by using scanners ([Tan and Vonderembse, 2006](#); [Chopra, 2018](#); [Brynjolfsson et al., 2013](#)). The web channel is advantageous for providing vast product variety towards the customers, and the operational practice facilitates easy navigation in the vast product supply.

As touched upon in the methodology chapter, [Sandberg and Alvesson \(2011\)](#) imply that this type of research claims a broader and more conceptual contribution to science, i.e., this exploratory design science needs field-testing ([van Aken et al., 2016](#)). Although there are fragments of the operational practice in real-life applications, the effectiveness of the systemic use of the operational practice from a system perspective remains to be researched. The shift of the performance frontier as accounted for in Chapter 6 gives a hint on how the operational practice can lead to a performance frontier shift in the case of Skates stocker. As for Dress shoe customizer, the operational practice facilitates a more accurate fit of custom-made products and a smoother, less iterative manufacturing process, but it is not deemed sufficient for shifting the performance frontier.

Next, the generalizability of results is discussed in terms of if the results are applicable to other industries than the footwear industry. Generalizability in relation to case studies is also discussed.

7.3 Generalizability of results

The focal industry in this thesis is footwear due to the existence of real-life implementations. Nevertheless, the operational practice includes any type of product in its definition and is not limited to footwear per se. As empirical

evidence is scarce due to the emergent nature of the phenomenon under study, generalization to other industries is, therefore, on an analytical level, as explained by Yin et al. (2017). The operational practice is generic in regard to its generic functionalities as outlined in Paper I. It further triggers valuable outcomes in regard to the maturity model developed in Paper II.

The operational practice is thought of as to lower inventory holding costs and obsolescence which are common challenges in retail supply chains (Wan and Sanders, 2017). Some industries that are particularly vulnerable to obsolescence are, e.g., the food, the spare parts, and the pharmaceuticals industries. In the food industry, the operational practice can be used to pitch customers about food that is running the risk of becoming obsolete, and supply chain actors can attempt to steer the sales to clear inventory of those products. The spare parts supply chains are complex in nature and stock spare parts for many years, and for many product variants. The automotive supply chain is an exemplar of an industry that supplies products with long life-cycles and requires that spare parts are stocked for many years after the vehicle has stopped selling. The operational practice would facilitate locating spare parts across the dealer network and even the rarest parts for veteran vehicles would be located. If the operational practice were to be applied to the pharmaceuticals industry, it could work as an assisting tool that detects clashes between medicines/ vitamins/ minerals or if they cancel each other.

8. Concluding remarks

This chapter concludes the research by elaborating on the contribution of the research and setting new directions for further research.

8.1 Conclusions

The research in this thesis studies an alternative way of bypassing the production efficiency-responsiveness trade-off in retail supply chains. The findings provide an understanding and explanation of what supply chain outcomes the operational practice triggers, in what contexts, and which mechanisms that affect the triggering of an outcome.

The operational practice could shift the performance frontier by improving market mediation performance in retail supply chains, particularly through improved delivery performance and cost performance, simultaneously. This thesis has shown how the performance frontier can be shifted in two distinct types of retail supply chains. The operational practice was initially intended for make-to-stock production to take advantage of economies of scale. However, a retailer was also analyzed which is using the operational practice for more efficient make-to-order production. This shows how the operational practice also has a role in make-to-order production. Such a role is to make the manufacturing process less iterative with the customer, which brings efficiency to the manufacturing process.

8.2 Theoretical and managerial contribution

The theoretical contribution of significance is an explanation and understanding of how the proposed operational practice can lead to a major shift in the performance frontier in retail supply chains. By using matching technology, it is possible to change the trade-off between cost performance and delivery performance in the supply chain, achieving much of the benefits of customization at a lower production cost. The operational practice matches digital product models representing physically available product supply to digital customer models representing the actual end-users. Given that there already is product supply available on the market, maximum delivery performance (responsiveness) is achieved, and given that companies strive for high productivity in the production of products, the available products on the market are cost-efficiently produced. By matching available product supply to customers in need or want of them, responsiveness and efficiency are achieved without a trade-off between the two. The research uses the theory of performance frontiers to explain and understand how the operational practice could move the performance frontier in retail supply chains.

This research relates to four research areas previously dealt with in operations and supply chain management literature aiming to improve performance and particularly the literature dealing with the cost-delivery trade-off. The first research area is performance capabilities and manufacturing strategy. This thesis relates to that area by drawing on factory focus as a means for achieving production efficiency. Factories should focus on their core competencies and competitiveness to stop compromising trade-offs within the factories. The second research area is supply chain design, and this thesis draws on previous supply chain design frameworks. The operational practice does not entail a choice between designing physically efficient and responsiveness supply chains. Instead, matching allows the combination of physical efficiency and responsiveness capabilities in the *same* supply chain. The third research area is supply chain performance, and this thesis relates to supply chain performance by developing an understanding of an alternative way of how the cost-delivery performance trade-off can be bypassed. The last and fourth research area is omnichannels, and the operational practice adheres to this area by enabling sales across retail channels. The operational practice acts as a product recommendation system that can recommend products across retail channels, and thus, enables sales across channels.

This thesis draws on four established research areas, but primarily contributes to one of them, i.e., supply chain design. The contribution relates to previous work on achieving the benefits of customization using the efficiency of mass production. Established supply chain design frameworks (Fisher, 1997; Pagh and Cooper, 1998; Christopher and Towill, 2001) distinguish between efficient and responsive supply chain designs. Mass customization literature focuses on combining efficiency and responsiveness, but a trade-off between customization benefits and mass production efficiency persists. This thesis complements the established frameworks with a framework for making the efficient supply chain design more responsive using the operational practice.

The managerial contribution and industrial relevance of the operational practice are significant. Retail supply chains are highly end-customer-driven and delivering the right supply of products that match customer demand is utterly important for retail supply chain success, nonetheless from a sustainability perspective. The findings in this thesis help companies understand how their profiles match the operational practice, and what outcomes to achieve given contextual factors.

The outcomes were captured in Paper II and formalized as seven propositions. The first proposition proposes that the operational practice provides in-shop operations efficiency at retailers such that store assistants can more accurately and efficiently provide customers with fitting products. The second proposition proposes that the operational practice can be used to engage in relationship-based sales and companies can start selling individual-based offers instead of pure transactional sales. The third proposition proposes that retailers can more accurately decide upon which assortment to offer, the better

knowledge of the customer base enables this. The fourth proposition proposes that product flows can be more efficient in both the physical and web retail channels since matching enables customers to fit fewer items. In web channels, operators pick fewer order lines otherwise occurring when the customer does not know which size to choose in web retail. In physical retail, store assistants do not need to bring as many sizes to the fitting room when serving customers. The fifth proposition proposes that the operational practice is useful for managing long-tail assortment. The sixth proposition proposes that the operational practice can be used to pitch new products to customer potentially benefitting the most from them. The last and seventh proposition proposes that digital customer models can be used by manufacturers to develop products that are well-aligned with customer demand.

The practice is conceptualized and introduced in a retail supply chain, demonstrating how it can be used by companies, this is done in Paper I. The proposed implementation of the operational practice is visualized in Paper I. Paper II develops a maturity model, describing three maturity levels of the operational practice on which companies can map their current state and desirable to-be state and to advance in level.

The findings in Paper III help companies to understand what supply chain outcomes to expect depending on the mechanisms present in their specific context. The findings are relevant for companies that pursue make-to-stock or make-to-order production. Companies can compare their operations with the operations of the two cases in the paper. If there are similarities, companies get a hint on what characteristics (products supplied, supply chain complexity, etc.) that are crucial for the triggering of an outcome.

8.3 Limitations and further research

Up until now, this thesis has studied how the use of digital models of customers and products can be matched to facilitate an efficient response in retail supply chains. The current research is comprised of the CIMO framework, studying the **I**ntervention, its **C**ontextual relevance, possible **O**utcomes, and **M**echanisms triggering the outcomes. However, what is not captured by the CIMO framework, and thus what remains to research, are several strands of research that directly build on the CIMO framework. These strands include to study the actor perspective of the operational, extending its product scope, and field-testing it.

8.3.1 Actor perspective

The actor perspective was briefly touched upon in Paper II; however, it is a much interesting strand of research to understand the operational practice as a business model and which tensions and opportunities there are between supply chain actors. As shown by this research, the operational practice has much potential to match supply and demand from a system perspective. Nevertheless, retail supply chains compete to serve customers and gain market

share, which obstructs the system benefits of the operational practice. From a system perspective, manufacturing companies could focus their operations on producing few products and product variants and optimize productivity. From a competition perspective, companies produce competitor-like products and have a broad product range. If the latter competition perspective is put in the system perspective, there is an increased risk of oversupply of products within the system. Therefore, it is much relevant to study the operational practice as a business model to better understand its implication for competing supply chains.

Talmar et al. (2018) propose the Ecosystem Pie Model to map, analyze, and design innovation ecosystems. It is useful for studying constructs and relationships that capture how actors interact in an ecosystem to create and gain value. Such a model is especially fruitful in order to study the top maturity level of the operational practice, i.e., the systemic use of the operational practice from a system perspective.

8.3.2 Product and supply chain scope

Another strand of research is to broaden the product scope of the operational practice. Thus far, the focus has been on products where the physical fit is important (Paper II). However, the operational practice is likely valuable for other product types with other fitting attributes. As was shown in Paper II, the operational practice with related outcomes is relevant for products where product and customer attributes are easily measurable, and two such product types are groceries (allergies, diets) and pharmaceuticals. In grocery supply chains, e.g., the practice is appropriate for finding products based on macro (fats, proteins, and carbohydrates) and micro (vitamins and minerals) nutrition specifications. A customer with a purchase history of almonds may not be content with the product recommendation of hazelnuts because of allergy. The two foods may appear exchangeable from the supplier perspective but may appear very different from the customer perspective. For pharmaceuticals, the operational practice would detect which pharmaceuticals that fit the customer but would also detect which pharmaceuticals that clash or cancel each other. A certain assortment of health products can be matched to customer profiles with certain known and diagnosed health risks or disease. However, the thesis has not studied the operational practice with other matching attributes than physical fit, and consequently it is left for further research.

Paper II was first designed to investigate the contextual fit of both products and supply chains, but the focus leaned towards products, and thus the supply chain contextual fit was given less focus. Context is important in the CIMO framework and in operations and supply chain management research overall since policy and procedure implementations are context-dependent. Paper III contributes with supply chain context to the operational practice to some extent, yet the focus is on mechanisms, such that context is put aside. Therefore, the supply chain contextual fit is left for further research.

8.3.3 Field-testing

Since matching of digital models is an emergent phenomenon, rigorous empirical evidence for its effectiveness is lagging. Field-testing is crucial for practical validity in design science research. In this thesis, the practical validity is acknowledged as a limitation. Nevertheless, investing in new ways of operating in order to move the operating frontier is risky for companies when the implications that follow the introduction of the new operating technology are unknown. For accurate risk assessment, the new technology should already be in use, but this is seldom the case in reality. This paradox calls for a prescriptive and exploratory design science research approach used in this thesis. Since there is little empirical evidence to support the operational practice in a system perspective, this research has been based on case research of already existing similar practices. The idea of this research is to provide the best possible evidence from these existing practices to attain an understanding of the implications that will follow the introduction of the operational practice. Further research includes to field-test the operational practice.

Such field-test could be to introduce the operational practice as a platform across a network of retailers in order to test a prototype and to analyze and evaluate its effects on retail supply chains. Such prototype would provide empirical data for evaluating proposed outcomes and the operational practice as a business model.

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